Problem structuring: A study on the available methods and their integration and effective proposition for successful interventions

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Problem structuring:
A study on the available methods and their integration and effective proposition for successful interventions

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DEDICATION

To Kami,
May your soul rest in peace

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ABSTRACT

Several critical elements (such as uncertainty, complexity and lack of structure) limit the use of analytical models and methods in problem solving and decision-aid in practice. In an effort to solve these problems, the initial representation or conceptualization of a problem is so crucial to its subsequent treatment that one is tempted to say that the most important as well as most difficult issue underlying the subject of problem solving is precisely 'how to structure the problem'. The purpose of study is to review concepts related to the problems that require structuring (ill-structured or unstructured problems), the methods that are available in order to deal with these problems (problem structuring methods) and to study the use of these methods in interventions. The research involved creation of a community with the aim of integrating competences on how different methods may be used and integrated to face complex and unstructured decision situations, in order to develop methodological skills that could effectively facilitate the analyst's work. Each member of this community was involved, at the start in relation to a specific old intervention, in an investigation project, in relation to some cases and their modeling processes, which have been developed in real organizations, by means of a specific technical approach or with the support of a multimethodology with formal tools that propose a limited quantification within a systematic framework. Therefore the operational idea for the investigation was a procedure at two phases, the first for the creation of a knowledge base for the second phase and the second of interaction with the author of the paper that describes an intervention case. The information gathered from the community provided important insights into the problem structuring interventions and the results aim to facilitate the analysts to have an idea about the competences that need to be developed for a successful intervention.

INTRODUCTION

In the previous four decades, new tools, methods and methodologies have been developed in order to deal with "messes" or complex real world problem situations. These methodologies are known as Problem Structuring Methods (PSM), soft systems or soft OR and prime examples include Soft System Methodology (SSM), Strategic Choice Approach (SCA) and Strategic Options Development and Analysis (SODA). Problem structuring methods have now flourished in terms of practicality and also in terms of literature. These methods have been used either individually or in a combination with other methods (multimethodology) in order to address problem situations. However, there are still some questions to be answered about these methods like which of the methods can be included in the umbrella term of Problem Structuring Methods or soft OR. Moreover, there is also a considerable geographical limitation of these methods as they are more commonly used in UK, Australia, New Zealand and Canada as compared to USA and continental Europe (Ackermann, 2012). There are also concerns about the process of applying PSM as it is complicated, requires times and facilitating skills. Therefore, the aim of the doctoral thesis is to dig deep into literature and try to find the answers of these questions and to propose improvements.

In the period following World War II, many great minds were focused on the mathematical modeling of structured problems. Structured problems come with complete information, and are typically repetitive or routine. In a well-structured problem, the objectives are clear and the feasible alternative solutions are often obvious (Simon, 1960). However, this focus on modeling was tightly coupled with the emerging quality movement. The idea of this movement was that in case of unstructured problem situations, modeling cannot provide a feasible way to address the high level of complexities and uncertainties involved. These unstructured problems have characteristics completely opposite to well-structured problems. Ill-structured problems, in simple terms, tend to be complex, non-routine, and difficult to define. Potential alternative solutions, objective(s) associated with solving these problems, and the relevant decision makers and stakeholders, are often not obvious. The data required to model the problem are usually not readily available. The main characteristics of the unstructured problem will be discussed in detail in the state of art along with the ideas presented by the pioneers of the field in order to address these problem situations. Ackoff, who is considered as one of the fathers of operations research, provided us with a clear concept of an unstructured problem and the system approach in order to address it. This systems approach was necessary because of the influx of new 'problem complexes' or 'system of problems' described by Ackoff as 'messes' or 'unstructured reality'. His approach to systemic problem solving is to dissolve complex societal or organizational problems by engaging stakeholders in designing permanent solutions. He often quoted Einstein's warning that, *"We can't solve problems by using the same kind of thinking we used when we created them."* To manage a system effectively, one must focus on the interactions of the parts

rather than their behavior taken separately which means using systems thinking as opposed to an analytical approach.

Another important name in this regard is Churchman (an American Philosopher and system scientist) who is considered as a founding father of management science and operations research. In addition to the system-thinking approach, Churchman's contribution is important for adding an ethical or epistemological dimension when addressing unstructured problem situations. The manner and gist of his commitment to address the 'problems of the society' in accordance with ethical morality were clearly stated first in an exceedingly significant article published in 1965 in Management Science, and later in his book *The Systems Approach* in 1968 (Churchman, 1968). In the article, the authors called for 'mutual understanding' between operational researchers and managers as a means of tackling 'social problems' (Churchman and Schainblatt, 1965). Similarly, other important names and their ideas have been presented in detail in the first chapter.

Interestingly, the ideas presented by Ackoff and Churchman became much more famous in UK as compared to America. In the USA, the focus remained on solving well-structured problems in a traditional way using modeling approaches and development of mathematical techniques (Kirby, 2003; Mingers, 2011). Ackoff and Churchman were critical of such approaches and by researchers in order to tackle real life problems. There was a considerable debate at that time about the authenticity, validity and effectiveness of these 'soft' methods and whether they can be included in the Operations Research field or not (Machol, 1980) but they became gradually accepted particularly in UK. Checkland's Soft System Methodology (SSM) is one example of these soft approaches (Checkland, 1972; 1981) some of the others are Strategic Choice Approach (SCA) and SODA. The main criticisms of Soft OR are related to its subjectivity and the difficulties in the process. There are also confusions over which methods can be called as problem structuring methods. This forms the first problem addressed in this doctoral thesis.

Problem (1): Which of the methods and tools can be included in the umbrella term of Problem Structuring Methods?

Is there a shared definition of PSM? If not, which could be an operational definition, not in contradiction with the researchers' points of view? (Which methods have been included by researchers in their lists of PSM? What are the criteria used by researchers to create these lists? Can other methods be included?

Mixing different methods, from different fields and with different goals, has always been a way to increase the effectiveness of the interventions in complex and unstructured problem situations. Therefore, researchers and practitioners have the opportunity to mix methods form different fields in order to address the problem situation. As already explained, problem structuring methods are the amalgamation of system science and MS/OR concepts. (Galliers and Land, 1987) suggested that there are different approaches available and in order to tackle the complexity, the positive aspects of different approaches can be used to make results more

acceptable. (Jackson, 1990) created a categorization of systems methodologies that would allow for their complementary use in specified problem situations.

This approach, that combines together more than one method or methodology (in whole or part) within a particular intervention (Mingers and Gill, 1997), is now called *multimethodology*. *"Multimethodology is not the name of a single methodology or even of a specific way of combining methodologies together. Rather it refers to the whole area of utilizing a plurality of methodologies or techniques or techniques within the practice of taking action in problematic situations (Mingers and Gill, 1997)"*. This mixing of methodologies can become very complex, for example when mixing 'parts' of methodologies from different paradigms in a single intervention (Jackson, 1990) or managing the diversity of methodologies within an intervention (Flood, 1995). This idea forms the basis of our second problem statement.

Problem (2): Multimethodology

Why is there a need of integration of different methods? How different methods are combined and with which results or difficulties? Which is the role of PSM in multimethodology?

Problem Structuring is a flourishing field with a lot of research on theory and practice of methods. However, there is still a gap in literature as far as the process of intervention for PSM is concerned. Some of the researchers have discussed the intervention process while focusing on the theoretical aspects of problem structuring while others have focused on the practical aspects. However, there is a gap in literature on how to study PSM interventions but there is a general consensus that PSM interventions are complex events. The work of Keys is important in this regard (Keys, 1998; 2006). Moreover, the role of facilitator or expert is extremely important but there is still not a lot of research carried out in this domain. This idea forms the third problem discussed the thesis.

Problem (3): Problem Structuring Interventions and competencies

How can the Problem Structuring intervention process be improved? What are the proposals to remove difficulties in interventions? What is the role of facilitators in a Problem Structuring intervention? What are main drawbacks of PSM? How can they be identified? What are the main competencies required for a successful use of PSM?

This part is faced by means an application that analyses the Problem Structuring part of an intervention and in few cases the use of a PSM.

This thesis has been divided into two main parts: state of the art and the application. First part consists of three chapters and provides the theoretical background in order to understand the need and purpose of developing problem structuring methods. Second chapter deals with the state of art of problem structuring methods and a discussion about the methods that can be included in the list of PSM. Several sources of knowledge have been mentioned and discussed in

order to have a complete theoretical understanding of the key concepts. This chapter also deals with identifying the list of PSM used by different researchers along with the implicit and explicit criteria that is used to make the list. Criteria for PSM have been proposed which can be useful in identifying which methods can be included in the umbrella term of PSM. Third chapter is concerned with the explanation of multimethodology and the integration of Multi criteria decision analysis (MCDA) with PSM is taken as an example. Possible integration of MCDA with different problem structuring methods has been discussed. Part two of the thesis is the applicative part which deals with the process of PSM intervention and explores how competences can be developed for PSM interventions in light of Keys (2006) proposals. The final results achieved by the help of research have been explained in the result section followed by a list of references.

Research Aims and Objectives

This thesis aims to provide readers with the fundamental understanding of PSM, multimethodology and PSM expertise concepts. This thesis aspires to present answers related to some specific goals (SG):

- (SG1) To analyze the state of art of problem structuring methods and the competences required for a problem structuring intervention
- (SG2) To develop an operational definition of PSM, by means of a) a critical analysis of the different lists of PSM that are present in literature, b) the analysis of the explicit and implicit criteria that have determined these lists, c) the proposal of a motivated classification of the problem structuring tools and methods that are used in literature and used in real problem situations
- (SG3) To explore the multimethodology concept in detail (why it is required? How it is implemented) and investigate a frequent example of multimethodology: the integration of PSM with MCDA
- (SG4) To establish understanding of expertise required for PSM intervention in light of literature and to propose suggestions for the improvement of competences development

Methods and Procedures

SG1. The state of art is based on a detailed literature review that provides detailed information related to problem structuring methods and their interventions. The research includes the analysis of journals, conferences, books and white papers. Main sources of information are the Journal of Operations Research Society, European Journal of Operations Research and different books that have been cited.

SG2. A list of PSM was one of the goals of this thesis. This was done by analyzing and elaborating the list of PSM used by various researchers in their works. The implicit and explicit criteria used by these researchers in order to make the lists were identified and explained. The aim is to make the boundaries of PSM clearer and also to identify similar methods which can be used for the purpose of problem structuring.

SG3. Multimethodology concept explanation was done by identifying the need of the integration of different methodologies and the process of multimethodology (not only from the point of view of operation researchers but also from other points of views like system sciences). The literature review also identified the most common methods that are used in combination with each other. As an example of multimethodology, the integration of PSM with MCDA was explained in detail.

SG4. As far as the PSM intervention process and competences are concerned, the main guideline used was from Keys paper on the ways to become expert in problem structuring methods (Keys, 2006). Keys proposes a community of academics and practitioners, that should be developed to facilitate the diffusion and use of problem structuring methods, and an actor network framework that can help facilitate the decision making process.

A community was developed, similar to the proposal of Keys, with the aim of integrating competences on how soft and hard OR methods may be used and integrated (sometimes with non-OR methods) to face complex and unstructured decision situations, in order to develop methodological skills that could effectively facilitate the analyst's work. Therefore our operational idea for the investigation is a procedure at two phases, the first for the creation of a knowledge base for the second phase and the second of interaction between analyst and the author of the paper that describes an intervention case.

Part-1
State of the Art

CHAPTER 1
UNSTRUCTURED PROBLEM SITUATIONS

The purpose of this chapter is to develop a coherent understanding of the complex problem situation that couldn't be addressed using traditional OR and gave rise to soft OR. We will take a journey from traditional OR methods to the present situation of OR. The questions to answer are:

- What was the need of different approaches/tools/format/methods that forced the researchers to propose the idea of soft OR?
- What were the fundamental shortcomings of traditional/technical OR?
- Who were the main researchers in this regard and what were the ideas they proposed?
- If researchers in other fields like urban planning, System engineering or system analysis provided similar ideas, shouldn't they be included?
- What are the origins of terminology of 'soft OR'?

This chapter is divided into three parts:

1. In the first part we will describe the leading reformist in the field of OR that provided their important ideas in order to diverge the OR field to deal with real world complex problem. In this section, special focus is on the landmark work of the researchers in their field and the principle of the development of their ideas. Starting from Churchman's ethical influence on OR and Ackoff's systems approach, we have tried to cover the literature about their ideas and critique of traditional MS/OR. Checkland's soft approach and the critical aspect of Jackson's work have also been mentioned. The main focus is on the researcher's original words in literature in which they have discussed the various aspects of OR.

2. Second part includes the comments of researchers in different context from OR like urban planning, philosophy and environment. We will develop an understanding of the type of problems that can be addressed by using soft OR. These ideas from different fields can also be addressed using OR and OR researchers have used these ideas in their works.

3. Third part summarizes the shortcomings of traditional OR and the need of the development of soft OR. The main focus is on the origins of OR.

1.1 Point of views of leading reformers of Management Science/ Operations Research and System Science

1.1.1 Churchman's Ethical Influence

C.W. Churchman (1913- 2004) was an American philosopher and system scientist and also considered as a founding father of management science and operations research. He advocated for a philosophical change in the way operational researchers and management scientists

conceived the problems by comprehending the ethical dimension of system (Ulrich, 1994). Churchman, in collaboration with Ackoff and Arnoff, has the distinction of publishing the first genuine textbook of Operational Research in 1957 (Churchman et al., 1957). In this book, the fundamental characteristics of operational research were eloquently explained and also the applications of OR outside the military domain were emphasized. The authors viewed a system as **'an interconnected complex of functionally related components'**, which should be tackled by using a 'team approach':

> *"Another important advantage of the team approach lies in the fact that most man-machine systems have physical, biological, psychological, sociological, economic, and engineering aspects. These phases of the system can best be understood and analyzed by those trained in the appropriate fields…"* (Churchman et. al, 1957)

This idea of an inter-disciplinary approach turned out to be one of Churchman's persistent concerns. Churchman also had distinction of being the founding editor-in-chief of the journal ***Management Science***. In an editorial, Churchman laid the foundations for the goals and ambitions for the journal with the same idea of inter-disciplinarily approach:

> *"All these philosophers the mathematical purist, the adherent to hard facts, the generalize, the "case" man all are committed to a conviction that a science of management will stand as a legitimate and recognized field of scientific endeavor. Some are committed to a conviction that this science will stand as the greatest scientific discovery of our age all are committed to the conviction that no other field of endeavor is as important to man as the field which searches for truths about the ways in which men work and live together. Management Science is committed to the conviction that all these philosophies should be given expression in its pages in articles that emphasize mathematical models, that emphasize measurement and control, that emphasize broad viewpoints, that emphasize specific cases and methods no matter what the origin of the writer may be mathematician, physicist, social scientist, biologist, engineer, manager and non-manager philosopher"* (Churchman, 1955)

In this editorial, Churchman clearly defines the scope of the journal that it will address the social 'truths' irrespective of the field of the researcher which means that a coherent cooperation among researchers in different fields addressing the social problems. Same ideas can be found in other works of Churchman. The manner and gist of his commitment to address the 'problems of the society' in accordance with ethical morality were clearly stated first in an exceedingly significant article published in 1965 in Management Science, and later in his book ***The Systems Approach*** in 1968. In the article, the authors called for 'mutual understanding' between operational researchers and managers as a means of tackling 'social problems' (Churchman and Schainblatt, 1965). It is important to consider the environment and the timing of the book when the world was involved in a space race and to reach moon. Churchman questioned the objectives of

approaches of 'space age' related to the expeditions to the moon when there are so many terrestrial problems. In his words:

> *"We need to feed, shelter, and clothe the world subject to conditions that create a free society. We don't believe that the way to solve the problems of mental and physical health is by the elimination of the mentally and physical diseased.*
>
> *What do we wish to accomplish? Can we actually state an objective that is as operationally clear as the objective of landing an object on the moon, subject to budgetary constraints? Or is it a foolish waste of time for us to think about the objectives of the inhabitants of the world in such terms?"* (Churchman, 1968a)

Thus, Churchman provided the readers the basic questions about how to think with objective **'**to explore…some basic ideas on how to think in our century'. He also provided some main areas of focus:

> *"We will begin quite modestly at first, not with the problems of the whole world, but with the problems of some very specific systems. Our chief interest will not be in hardware systems like the rocket to the moon, but rather in systems with humans in them. These are systems like industrial firms, hospitals, educational institutions, and so on."* (Churchman, 1968a)

MS/OR involves making decisions that leads to some improvement. Churchman argues that real improvement can never be achieved without **incorporating ethical and epistemological concerns.** Furthermore, Churchman questioned the approach where decisions are made without understanding the totality of a system:

> *"How can we design improvement in large systems without understanding the whole system, and if the answer is that we cannot, how is it possible to understand the whole system?"* (Churchman, 1968b)

For Churchman, this means that traditional analytical methods need to be balanced with a *'sweep in'* process (Churchman, 1982) that is, a systematic and self-critical attempt to consider ever more aspects of the larger system or the totality of the relevant system.

Churchman's work was extremely important in the context that he developed a logical and clear range of ideas on the boundary of OR, management science and system thinking (Checkland, 1999). Nobody can deny the extraordinary contribution of Churchman in the literature of OR, management science and systems analysis. For his ethical morality ideas, Churchman has been referred to as **'the moral conscience'** of research in business and management — which is further endorsed by his nomination for Nobel Prize in the field of social systems (Warner, 1998). Churchman was also the philosophical mentor of Ackoff (discussed in the next section) and both of them collaborated in questioning the traditional

approaches of OR with system thinking approach and also in the dimension of ethical rationality. The landmark of his work was a deep concern for social purposefulness with the aim of boosting the quality of life for all the citizens in the world although Churchman was equally concerned about the ethical morality of decisions and resulting courses of action.

> *"My notion was that a society and journal in the subject of a science of management would investigate how humans can manage their affairs well. For me, "well" means "ethically," or in the best interest of humanity…"* (Churchman, 1994)

1.1.2 Ackoff's System Approach

Russell Ackoff (1919-2009) was an Operational Researcher and a Professor of Management Science at the University of Pennsylvania. He is considered as a pioneer in the fields of operations research, management science and systems thinking. Ackoff also has the distinction of being an "exceptional advocate and diffuser of OR beyond the USA from the mid-1950s onwards" (Kirby, 2003). Ackoff's criticisms of the traditional OR up to 1979 are well documented in the literature (Ackoff, 1977; 1979a; 1979b). In 1959, Ackoff and Sasieni published a book called "*Fundamentals of Operational Research*" in which authors advocated for a combination of 'mathematical treatment of the subject with a conceptually oriented qualitative treatment' (Ackoff and Sasieni, 1959). This book is also notable for Ackoff's viewpoint of expanding the borders of traditional methods in order to address 'long-range strategic planning issues'. In his view, OR had become confined to the traditional mathematical models 'dealing with problems of limited scope' which will have negative effects on the field in the future as researchers will try to fit these models into all the problems. In the worst case scenario:

> *"If they [the researchers] cannot find such problems they will be increasingly inclined to distort the problem so that their favorite technique can be applied. If OR is to survive it must maintain a strong problem orientation, not a technique orientation. It must expand its methods and techniques to fit the problems and not contract the problems to fit available methods and techniques."* (Ackoff, 1961)

Also in Ackoff's view, the scope of OR was

> *"Not broad enough to research effectively the operating characteristics of our social system that most urgently need research: discrimination, inequality within and between nations, the bankruptcy of education, the inefficiency of health services, increasing criminality, deterioration of the environment, war, and so on."* (Ackoff, 1973)

In order to address the situation and to make sure that Operational Research expands its boundaries beyond the traditional modeling to address real world situations, Ackoff used the concept of new systems approach into OR which was defined by Ackoff in these words:

> *"A system is more than the sum of its parts; it is an indivisible whole. It loses its essential properties when it is taken apart. The elements of a system may themselves be systems, and every system may be part of a larger system.*
>
> *Preoccupations with systems bring with it the synthetic mode of thought. In the analytic.... an explanation of the whole was derived from explanations of its parts. In synthetic thinking, something to be explained is viewed as part of a larger system and is explained in terms of its role in that larger system. For example, universities are explained by their role in the educational system, rather than by the behavior of their colleges and departments. The Systems Age is more interested in putting things together than in taking them apart."* (Ackoff, 1973)

This systems approach was necessary because of the influx of new 'problem complexes' or 'system of problems' described by Ackoff as 'messes' or 'unstructured reality'. According to Ackoff, **"Every problem interacts with other problems and is therefore part of a set of interrelated problems, a system of problems…. I choose to call such a system a mess"** (Ackoff, 1974). Ackoff also described the nature of "messes". According to him, **"a mess is a system of constantly changing, highly interconnected problems, none of which is independent of the other problems that constitute the entire mess"(**Ackoff, 1979a). As a result, no problem that is part of a mess can be defined and solved independently of the other problems. Accordingly, the ability to manage messes requires the ability to think and to manage systemically.

Ackoff also underlined the inability of traditional modeling methods to deal with changing environment in particular political environment that is 'subject to substantial, unpredictable, and frequent changes'. These changes cannot be modeled and hence an "optimal solution", which is the objective of traditional methods, cannot be achieved. Consequently:

> *"It is silly to look for an optimal solution to a mess. It is just as silly to look for an optimal plan. Rather we should be trying to design and create a process that will enable the system involved to make as rapid progress as possible towards its ideals, and to do so in a way which brings immediate satisfaction and which inspires the system to continuous pursuit of its ideals."* (Ackoff, 1977)

Ackoff also has the distinction of being the champion of **"community OR"** when he engaged in working out the problem of black ghetto in Mantua (Ackoff, 1970). The paper entitled "A Black Ghetto's research on a University" begins with the appreciation of OR methods and their usefulness in 1950s and 1960s but at the same time warns that if OR is to continue to flourish and succeed, it must improve its effect on important social problems faced by society and

organizations. This involves changing the basic methodologies and philosophies of OR. Ackoff used the process of "interactive planning" to solve some of the problems faced by the black ghetto community. This interactive approach involved participants from community and researchers from university so that the black ghetto community could use resources and plan for their future development themselves. The ideas presented in this paper are important as they motivated researchers to involve OR in tackling social problems.

The work of Ackoff was an important landmark towards the defining the scope of OR and as history tells us that it sparked a big debate among researchers well into the 90's. He not only scrutinized OR approach but also proposed new ideas for tackling real world messy situations that is why he is considered both an 'apostate' and an 'apostle' of Operations Research (Kirby, 2003).

1.1.3 Checkland's 'Soft' Approach

Peter Checkland (born 1930) is a British management scientist and a retired Professor at Lancaster University. He carried forward the ideas of system thinking proposed by Checkland and Ackoff and developed 'soft' methodology in order to tackle real world complex 'messy' problem situations. He criticized the 'classical OR' approach which involved model making where a substitute of real world was made in order to perform experiments and results transferred to the real world. He implied that in wartime situations (classical OR main application area), it was possible because of the lasting stability of many of the variables involved so that the total results were relatively constant. Hence, classical OR involved model building with experimentation and in many situations it is not possible to create models as the variables involved are constantly changing or the problem cannot be structured in the form of a model. Checkland, from 1980 onwards, became the leading proponent of 'soft' approaches by developing 'Soft System Methodology' (SSM) as a response to the limitations of classical paradigm of OR (Checkland, 1981). His publications were notable because of his acknowledgement of Ackoff and Churchman's 'system' approach because Checkland's 'soft' approach and Ackoff's 'systems' approach both are used to tackle **"management situations in which objectives were problematical and the engineering/optimizing of the approaches developed in the 1950s and 1960s could not be used unchanged."** Thus the major difference between the classical 'hard' paradigm and 'soft' approach was the way in which they utilized system ideas. In Checkland's view, systems thinking included the ideas of hierarchy, control and communication. He suggested that both hard and soft approaches involve the use of these basic concepts of systems thinking but the main difference lies in the purpose of their use:

> *"The main difference between 'hard' and 'soft' approaches is that where the former can start by asking 'What system has to be engineered to solve this problem?' or 'What system will meet this need and can take the problem or the*

need as 'given'; the latter has to allow completely unexpected answers to emerge at later stages." (Checkland, 1981)

Furthermore, in a chapter in book entitled "Encyclopedia of Operations Research and Management Science", Checkland elaborated that:

> *"The soft approaches …do not assume that systemicity lies in the world. Their assumption is that whatever the real world consists of (on which they are neutral), the process of inquiry into the world can be organized as a learning system. Thus in SSM the system is the process of inquiry itself—though SSM also happens to make use of systems models of purposeful activity, though these are not would-be descriptions of anything in the world, only devices to structure the debate."* (Checkland, 2001)

The differences between soft and hard approaches can be further summarized in the following table:

Table 1.1
Hard vs. Soft Approaches (Checkland, 1981)

	Hard	Soft
Problem situation	Straight forward	Mess (problematic)
Purpose	Problem solving	Problem structuring
Organisation	Given	To be negotiated
Methodology	Logical/mathematical model	Conceptual models
Result	Product/recommendation	Learning process

This table highlights the main differences between traditional hard methods and soft methods. The problem situation in soft methods is a mess that is not structured, involving multiple stakeholders with varying points of views unlike a hard situation in which the problem can be clearly defined and structured. The purpose of a hard approach is to solve the problem while in soft method it is to provide a structure to the mess without looking for an optimum solution. Despite of all these differences, Checkland underlines that:

> *"The soft methodology is seen to be the general case of which hard methodologies are special cases. Thus conceptualization becomes, if the problem is sufficiently well defined, systems design. 'Improving a conceptual model' sharpens up into 'optimization of a quantitative*

model'. Implementing some variety of change becomes implementing a designed system." (Checkland, 1981)

This is important because according to Checkland, hard and soft approaches are complementary to each other and their results are "powerful" in combination. This view stands in complete contrast to Ackoff's as he completely rejected the classical paradigm. According to Dando and Bennett, OR is divided into three paradigms. "Classical" or "positivist/quantitative" paradigm was based on quantitative "methods of science." Ackoff belonged to the "reformist" paradigm while Churchman belonged to the "revolutionary" paradigm as both classical and reformist schools of thought were rejected in his works and publications (Dando and Bennett, 1981).

1.1.4 Rosenhead's 'Alternative Paradigm'

The Third school of thought according to Dando and Bennett were 'revolutionaries' that began their critique of traditional "classical" paradigm of OR from 1970s onwards (Dando and Bennett, 1981). These critiques mainly emerged from the British institutes that can be well explained by the external environmental conditions such as economic problems and political turmoil in UK at that time. According to (Kirby, 2007) these problems in the decade of 1970 can be explained as follows:

1. The slowest rate of economic growth since the early 1900s and exceptionally poor growth performance in relation to the leading developed economies.

2. A period that witnessed the loss of more than 2 million jobs in the manufacturing sector, giving rise to a major debate on the causes and consequences of "deindustrialization."

3. The bankruptcy of "flagship"/prestigious firms in the manufacturing sector and their takeover by the state (notably, Rolls Royce in 1971 and British Leyland in 1975).

4. Exceptional turbulence in industrial relations, focusing on the nationalized coal industry where there were strikes in 1972–1973 and 1973–1974, and the latter resulting in the electoral defeat of the governing Conservative Party.

5. Failures in macroeconomic policy intensifying an existing "boom and bust" cycle, the product of unprecedented growth in the money supply, and the public-sector borrowing requirement.

6. A major exchange-rate crisis in 1976 when the government of the day was obliged to seek the support of the IMF on terms which were viewed as "humiliating" and certainly

consistent with the IMF's policy of responding to the monetary needs of "third-world" countries.

7. The inflationary consequences of the OPEC-administered oil-price hike in 1973–1974, bear in mind that the British inflation rate in the mid-1970s was by far the highest among OECD countries.

8. A sense of mounting political concern about the future of the British state itself (reflected in journal and newspaper articles on the theme, "Is Britain becoming ungovernable?") in view of the rise of trade union militancy and nationalist political parties in the Welsh and Scottish "Celtic" fringe. The prevalent problem of Northern Ireland was also at its height.

9. The collapse of the post-1945 consensus on economic policy, whereby the maintenance of full employment was replaced by the control of inflation as the overriding policy objective.

These were the main reasons why the revolutionaries and reformist schools of thought emerging in that period mainly in the UK (Kirby, 2007). This can also explain the lack of such ideas in the American OR practices, as American political and economic situation was better.

Rosenhead was one of the leading names belong to the revolutionaries paradigm. He agreed with Ackoff's views about the limit of traditional OR methods and their reliance on mathematical modeling, but he disagreed with Ackoff's idea of participatory and interdisciplinary standpoint. According to Rosenhead:

> *"From the earliest days [of capitalism], the organized workforce has resisted [management exploitation] in fierce and sometimes locally successful struggles. But in the struggle between management (who act in this respect as agents of capital) and labor, the initiative has lain with management. On its behalf theories have been developed and techniques introduced in steady succession. The result has been the battery of sciences on which management now relies for the design and control of the work-process and the control of the workforce. These include time-and-motion study, production engineering and ergonomics (also called human engineering), as well as the various schools of industrial psychology, industrial sociology and organization theory. This proliferation of specialisms can be seen simultaneously as elements in a Taylorist offensive and as managerial tactics aiming to head-off the workers' passive or active response.*
>
> *Operational research is one of these management sciences. And both these tendencies—to control the workplace and to control the response—are present within it. It is part of the forces of production 'the resources and knowledge at*

> *the disposition of society to make use of nature' which under capitalism are the means by which the work-force is more efficiently exploited; and it is part of the ideological superstructure, the dominant system of ideas which dictate that the workers must accept the conditions of their exploitation."* (Rosenhead and Thunhurst, 1982)

For Rosenhead and Thunhurst, Ackoff's approach was not suitable for some problem situations, as it doesn't take into account conflicts between different hierarchical levels in an organization. Ackoff advocates the use of "team approach" where everyone works together with one objective but Rosenhead disagrees because of the bureaucratic struggles in an organization. In this regard, Rosenhead proposed 'an alternative paradigm' as a substitute to the traditional "dominant paradigm" so that it is possible to move forward from the critiques of traditional OR towards remediation (Rosenhead, 1989). The characteristics of these paradigms can be viewed in Table 1.2 and Table 1.3. Rosenhead's aim in proposing these characteristics is not to produce a checklist for users in order to compare different approaches but it is used to differentiate dominant paradigm with alternative paradigm and the main focus of the approach used in it. It is possible that some methodologies focus on one characteristic in particular but the overall theme of methodology remains confined to the broader space of these characteristics. Rosenhead's book "Rational Analysis for a problematic World", in which these characteristics have been explained, is extremely important.

Table 1.2
Characteristics of a dominant paradigm of OR (Rosenhead, 1989)

1	Problem formulation in terms of a single objective and optimization. Multiple objectives, if recognized, are subjected to trade-off on to a common scale.
2	Overwhelming data demands, with consequent problems of distortion, data availability and data credibility.
3	Scientization and depoliticization, assumed consensus.
4	People are treated as passive objects.
5	Assumption of a single decision maker with abstract objectives from which concrete actions can be deduced for implementation through a hierarchical chain of command.
6	Attempts to abolish future uncertainty, and pre-take future decisions.

Table 1.3
Characteristics of an alternative paradigm of OR (Rosenhead, 1989)

1	Non-optimizing; seeks alternative solutions which are acceptable on separate dimensions, without trade-offs.
2	Reduced data demands, achieved by greater integration of hard and soft data with social judgments.
3	Simplicity and transparency, aimed at clarifying the terms of conflict.
4	Conceptualizes people as active objects.
5	Facilitates planning from the bottom-up.
6	Accepts uncertainty, and aims to keep options open for later resolution.

Rosenhead elaborates further that methods that fulfill these characteristics exists and it is not just a conceptual or 'theoretical blue print for a form of analytic assistance'. But now the question arises that what makes Rosenhead's approach different to that of Checkland's? Checkland (as already explained in the previous section) focused on systems thinking and system approach but for Rosenhead, a more qualitative approach facilitated by cause-effect relationships of problem situation was of greater concern.

> *"The specification I have outlined for a decision-aiding technology more appropriate to messy, strategic problems eliminates much of the scope for advanced mathematics, probability theory, and complex algorithms (as practiced, for example, in decision analysis and the analytic hierarchy process). It identifies, rather, an alternative approach employing representation of relationships, symbolic manipulation, and limited quantification within a systematic framework."* (Rosenhead, 1996)

1.1.5 Jackson's 'System of system Methodologies'

Michael C. Jackson, born 1951, is Professor of Management Systems and former Dean of Hull University Business School. He has written 4 highly regarded books and edited 6 others in field of systems and management science. Jackson is considered as a major critique of the "classical" as well as of the "reformist" schools of thought. As already pointed out, Churchman and Ackoff used systems theory approach in expanding the horizons of OR but Jackson warns that although

there are many common factors between applied system theory (AST) and OR, their differences mean that they should be used with caution:

> *"Despite these crucial commonalities, that make OR and AST natural bed-fellows, advocates of the one often tend to know surprisingly little about the other. They have their own textbooks, journals and conferences and relate to their own communities of practice. Applied systems thinkers often refer to the classical textbooks and write off all OR as a form of hard systems thinking. Operational researchers have been known to see systems thinkers as either unscientific or impractical and too much in love with philosophizing."* (Jackson, 2009)

Jackson's critique of system approach used by Ackoff and soft system methodology used by Checkland sparked a huge debate in 1980s (Jackson, 1982; Ackoff, 1982; Churchman, 1982; Checkland, 1982). Jackson criticizes the subjectivity of soft system methodology that it doesn't take into account the impact and importance of social phenomena. Furthermore, he argues that the soft approach developed by Checkland is 'regulative' and cannot be changed in order to accommodate organizational, cultural and social uncertainties as well as to challenge traditions and beliefs (Jackson 1982, 1983). As far as the interactive and consensual approach of Ackoff, which involves multiples stakeholders working in team for one common goal, is concerned, Jackson says that it cannot be possible in real world organizational problems because "some issues never reach the agenda for debate," whereas some groups can be tricked by a "false consciousness" leading to the marginalization of their concerns (Flood and Jackson, 1991). Moreover, Jackson also disagrees with the nature of problem described by Ackoff and Checkland. He says that real world problems are far-too complex and have high uncertainty that they cannot be solved by just one approach. He proposes a system of system methodologies that help managers to choose a method depending on the type of problem they face. Jackson used 'critical' approach to address the inabilities of hard and soft methods; most important of which was their insufficient attention to power struggles that may arise in a consensual environment. System of systems methodologies (SOSM) was deployed by Jackson to create a categorization of systems methodologies that would allow for their complementary use in specified problem situations (Jackson, 1990). The main consideration in this approach is to assign a particular methodology for a specific problem situation. SOSM provides a matrix for classifying systems methods on two dimensions: one, the level of complexity of the problem situation (simple or complex), and the other dimension involves the classification of participants. Stakeholders are differentiated on the base of their common purpose. They are defined in a much better way in the Table 1.4.

Table 1.4
Classification of Participants (Flood and Jackson, 1991)

	Unitary	Pluralist	Coercive
Interests	Common	Basic Compatibility	No common interests
Values/Beliefs	Compatible	Slight divergence	Conflict
Ends and Means	Agreed upon	Compromise	Don't agree, compromise impossible
Decision making	Everyone involved	Everyone involved	Force others to accept
Objectives	Agreed upon	Agreed upon	No agreement

So Jackson proposed an understanding of the level of relationships between participants. Problem can be simple or complex so Flood and Jackson combined these dimensions to create a system of system methodologies for problem contexts as follows:

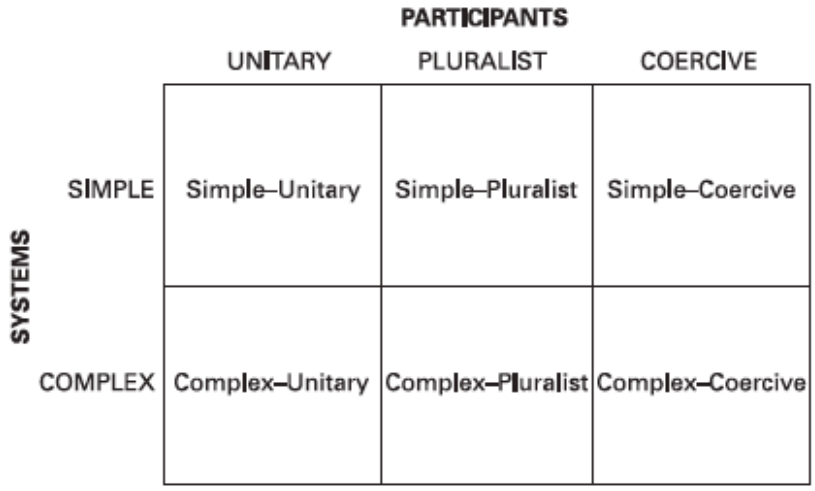


Figure 2.1: An "ideal type" grouping of the problem contexts (Flood and Jackson, 1991)

This figure depicts six "ideal type" problem contexts that imply the need for six types of "problem-solving" methodology (Flood and Jackson, 1991). About this methodology, Jackson says:

> *"O.R. is regarded by many as being in crisis. If O.R. is taken to be 'classical O.R.', this is indisputable. 'Classical O.R.' provides the practitioner with an approach suitable for solving problems only in*

mechanical-unitary contexts. If, however, the definition of O.R. is widened to embrace other systems-based methodologies for problem solving, then a diversity of approaches may herald, not crisis, but increased competence and effectiveness in a variety of different problem contexts." (Jackson and Keys, 1984)

1.2 Related comments in other contexts

In this section we will discuss other related concepts and ideas that have been proposed and developed by researchers not related to operational research but their proposed ideas have been used in the context of OR. Mainly the ideas are related to the various types of problems encountered in the real world. As Operational researchers strive to tackle real world problems, so it is important to have an idea of the different definitions of problem situations in other contexts. Most of these concepts have been included in research of operational researchers. We will discuss the ideas in this section.

1.2.1 The urban planning and the policy planning contexts

In 1973, two urban planners from University of Berkley, Rittel and Webber in their landmark article for policy planning used the term 'wicked' as opposed to 'tame' problems in these words:

"As distinguished from problems in the natural sciences, which are definable and separable and may have solutions that are findable (tame), the problems of governmental planning--and especially those of social or policy planning--are ill-defined; and they rely upon elusive political judgment for resolution (wicked)" (Rittel and Webber, 1973)

Their work highlighted the lack of ability of traditional quantitative methods to deal with problems widely encountered in urban planning. Although, Rittel & Webber defined wicked problems in terms of policy making and planning but the same idea of "wickedness" occur in any field involving various stakeholders with different viewpoints (Conklin, 2006). Political, economic and environmental problems are typical examples of wicked problems. A problem involving numerous stakeholders of different ideas and behaviors is expected to be a wicked problem. Hence, many standard examples of wicked problems come from the areas of public planning and policy. These include global climate change, natural hazards, healthcare, the AIDS epidemic, pandemic influenza, international drug trafficking, nuclear weapons, and nuclear energy, waste and social injustice.

The defining characteristics of a wicked problem are:

There is no definitive formulation of a wicked problem: Tame problems are characterized by a comprehensive formulation required by a problem-solver in order to provide the solution. This is

impossible in wicked problems because there are scenarios or situations instead of a specific solution. Therefore, knowledge of all possible scenarios is required beforehand so a formulation is not possible.

Wicked problems have no stopping rule: Tame problems have certain criteria that help a problem solver to know whether a solution has been reached or not. There are no such criteria in wicked problems. Other considerations like time, money or other resources can often define the stopping time but wicked problems do not have a specific rule to stop.

Solutions to wicked problems are not true-or-false, but good-or-bad: For tame problems, there are conventional criteria to know whether a solution is right or wrong and it can be verified by other people by inspection. Hence, a unique solution is reached. Whereas, in wicked problems the answers cannot be true or false. The involvement of different stakeholders with different opinions and knowledge means that their decisions are probable to differ widely according to their own interpretation and interests.

There is no immediate and no ultimate test of a solution to a wicked problem: Tame problems will generate solutions which can be analyzed at the spot in order to know how good the method has been but an implemented solution for wicked problem will generate waves of consequences over an extensive period of time. Until and unless all the waves of consequences completely run out, we cannot appraise the quality of the solution.

Every solution to a wicked problem is a "one-shot operation": In wicked problems, there is no opportunity to learn by trial-and-error so every attempt counts significantly. Every implemented solution is consequential. It leaves "traces" that cannot be undone … And every attempt to reverse a decision or correct for the undesired consequences poses yet another set of wicked problems.

Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan: There are no criteria which enable one to prove that all solutions to a wicked problem have been identified and considered. It can happen that no solution has been reached or (as normally happens) a group of possible solutions arises.

Every wicked problem is essentially unique: No two wicked problems are the same. It is possible that two problems have many similarities between them but there might always be a distinctive quality that is of extreme importance. Therefore, solutions of one wicked problem cannot be applied to another wicked problem.

Every wicked problem can be considered to be a symptom of another problem: Many internal aspects of a wicked problem can be considered to be symptoms of other internal aspects of the

same problem. A great level of common and circular causality is included, and the problem has many causal levels to consider. Complex judgments are required in order to determine an appropriate level of abstraction needed to define the problem.

The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution: There is no rule or procedure to determine the 'correct' explanation or combination of explanations (for a wicked problem). The reason is that in dealing with wicked problems there are several more ways of refuting a hypothesis than there are permissible in the [e.g. physical] sciences.

The planner has no right to be wrong: In tame problems, the researcher is allowed to make hypothesis that may turn out to be wrong. This process of making hypothesis generation and refutation is a driving force behind scientific development (Ritchey, 2001). Such leniencies are not provided to problem-solvers of wicked problems where they are held accountable for the outcomes of their decisions.

1.2.2 Philosophy and Professional learning contexts

Donald Schon (1930-1997) was a graduate in Philosophy from Harvard University but his most important contribution came in the field of professional learning. Just as Ackoff introduced the concept of "mess", Schon provided another idea to address problem situations related to a practitioner in professional learning. By extension, Schon's idea of "swamp" problems can be applied to address real world problems in other fields as well. In his book "Educating the Reflective Practitioner", Schon described "swamp" problems as opposed to "highland" problems.

> *"In the diverse landscape of professional practice, there is a high, hard ground overlooking a swamp. On the high ground, manageable problems lend themselves to solution through the use of research-based theory and technique. In the swampy lowlands, problems are messy and confusing and incapable of technical solution. The irony of this situation is that the problems of the high ground tend to be relatively unimportant to individuals or society at large, however great their technical interest may be, while in the swamp lie the problems of greatest human concern. The practitioner is confronted with a choice. Shall he remain on the high ground where he can solve relatively unimportant problems according to his standards of rigor, or shall he descend to the swamp of important problems where he cannot be rigorous in any way he knows how to describe in describing these problem situations."* (Schon, 1987)

1.2.3 Environmental Context

In 2007, Lazarus introduced the concept of "**super wicked problems"** (Lazarus, 2007) and then later in 2012, a group of USA and Canadian researchers (Levin K. et al, 2012) applied and extended the concept. In addition to the characteristics of wicked problems described above, super-wicked problems incorporate four additional points:

Time is running out: Super wicked problems include the time dimension. This means that these problems require urgent actions in order to address it. It also means that the longer it takes to address the problem, the harder it will be able to do so plus it will also incorporate additional cost factors that will disrupt the financial feasibility of entire project. For example, if green house gas emissions continue to increase exponentially, further efforts will be required in order to keep the levels downs. These will involve further technological advancements to make it possible. This means extra costs and economic disruptions that will make it much harder to address the problem (Lazarus, 2007).

No central authority: Another characteristic of super wicked problem that makes it different form a wicked problem is that there is no central authority that can address the issue. These problems are global in nature. In the environmental context, greenhouse emissions caused by rapid expansion of industries doesn't have any institutional framework of government that has the power to develop, implement and maintain the laws required to address the problem. Each country has developed its own laws but this is a global problem.

Those seeking to solve the problem are also causing it: This means that the people who have the power and ability to address the problem are themselves involved in part of problem or by reducing the problem can have a negative effect in some terms to them. For example, G8 is the group of 8 largest financial powers of the world with the power of imposing laws related to environmental change. Ironically, these are the countries that produce the most greenhouse gas emissions. Hence, if they impose laws on environmental policies, there own economic situation will suffer.

Policies discount the future: This means that humans discount the future that is; we are interested in short-term gains as compared to long-term investments. This characteristic is related to the first one (urgency) and adds another uncertainty to it that although these problems require immediate action, our on behaviors and policies don't like to focus too much benefits 50-100 years later.

1.3 The origins of the terminology "soft OR"

As already explained in Checkland's section, soft OR were developed by practitioners and academics in order to address the real-world problems. Some problems cannot be solved by the traditional OR approached such as linear programming or Markov process.

To summarize, we present some of the drawbacks of hard OR that have been explained in the previous sections. These drawbacks coupled with the environmental situations paved the way for soft OR. Some of the criticisms of hard OR are explained by Vidal (2006). There are criticisms concerned with the demand for quantification and optimization. When working with complex systems, the design of a quantitative model is inevitably a highly selective process and necessarily it will reflect the limitations and biases of its creators. Instead of recognizing this fact and making explicit the hidden assumptions, there is a tendency to treat the model readily as synonymous with the reality. Then the mathematical model becomes the focus of attention, and experimentation, manipulation and generation of optimal solutions is the main task of the OR worker. This causes that most attention is paid to the model and its solution than the real-life problem to be solved. Another consequence of the demand of mathematical modeling is the tendency to disregard those real factors that are not amenable to quantification or to distort them in the quest for quantification. Lastly, let us mention a critic point related to the implemented model, usually the users will not be able to understand the contents of the model, the results will be used as an act of faith, and in addition the user is not able to make changes in the model. In some situations the model will be given an important role in the problem solving process, it will be an authority, a computerized expert that is not able to explain in common language the way how the so-called "optimal solution" was found.

Another kind of criticism is related to the failure of OR to pay proper attention to the special characteristics of the human beings in the organizations, which they sometimes aspire to deal with. People, when included, are treated as components of a big machine that have to be adapted so that the whole system operates optimally. Here it is argued for another conceptualization of man, possessing understanding, having experience and his own personal knowledge and objective. This deterministic perspective in traditional OR thinking, which places the system before human beings, disregards the ability of man to intervene in their own destiny. Ackoff goes further and in this connection talks about the problem of humanizing organizations:

> *"Solution of this problem in whole-oriented organizations requires developing relevant incentives and ways of providing individuals with more meaningful participation in their organizations. Such participation implies giving individuals a role in making decisions that affect them directly and rewarding them appropriately for improved performance and increased responsibility. There is extensive evidence that such participation produces increased*

satisfaction and improves organizational performance." (Ackoff, 1974)

Finally, there are criticisms that point out the limitations of traditional OR in real-life problem solving. Hard/Technical/Traditional OR requires clear definitions at the start of problem-solving process. This is suitable for engineering-type of problems where goals are easy to specify and attention can be concentrated on means. However, in many situations of strategic art the very definition of objectives will be the main problem. Technical OR is suitable for that class of problems for which there is a desired state, D, and a present state, P, and alternatives ways of getting P to D. "Problem solving", according to this view, consists of defining D and P and selecting the best means of reducing the difference between them. In other words, technical OR consists of well-structured thinking related to means-determination in well-structured problems. The kind of problems adequate to the problem solving process of hard OR have been denominated as: well-structured, tactical, tame, or technical problems. Those problems where traditional OR seems inappropriate have been denominated as: ill-structured, strategic, wicked, or practical problems. In these last type of problematic situations or messes there will exist some general statement of a purpose to be achieved. The output of a study must propose some arguments in favor of accepting a way to structure the mess that leads to a corresponding means of solution.

Because of these criticisms and dissatisfactions of traditional OR, soft OR was developed to counter these limitations and involved the nature of individuals in the decision making process in organizations. Systems thinking, system analysis and operational research fields were included in the soft-OR context. Some basic characteristics of soft OR are as follows:

- Problem structuring using systems thinking approach
- Qualitative approach (interpretation, conceptual models etc.)
- Working for organizations where all the actors participate actively in the problem structuring and problem solving process, i.e. the operational researcher is a facilitator.

In Soft OR the attitude towards science is focused on the mental process of the practitioner. The phenomena or situation in study will be modeled based on the actors' subjective conceptualization of the situation and using such techniques as interviews, dialogue, discussions, work-shops, conferences, etc. Thus, practical OR offers a human-culturist approach to compare and contrast with the technical-naturalistic approach of traditional OR. In Soft OR, man is conceptualized as constantly creating and recreating the social world in interaction with others. In addition, in most soft OR approaches some of the principles of systems thinking will be used to structure the mess and to construct a conceptual model of the situation on hand. Ackoff (1974) pointed this out as Systems Age thinking.

Viewed structurally, a system is a divisible whole; but viewed functionally it is an indivisible whole in the sense that some of its essential properties are lost when taken apart. In the Systems

Age thinking things are looked as part of larger wholes rather as wholes to be decomposed. This is the doctrine of expansionism. Expansionism brings with it the holistic mode of thought, where something to be explained is viewed as part of a larger system and is explained in terms of its role in the larger system. The holistic way of though, when applied to problematic situations, is called the systems approach. This new way of thinking is necessarily interdisciplinary, that is a variety of relevant disciplines work cooperatively on the problematic situation as a whole.

Looking at these characteristics, it becomes evident to us that moving from hard OR towards Soft OR was an evolutionary step started by the criticism of Ackoff and Churchman. Their criticisms paved the way for Checkland to develop Soft System Methodology when for the first time he defined soft approach with the difference between hard and soft approaches. However, there was a considerable debate during the time as to whether these methods can be considered as an effective or a legitimate part of OR (Machol, 1980; Checkland, 1985). Even today the majority of publications in academic journals are dominated by quantitative analysis (e.g., Journal of the Operational Research Society). In fact, it was in January 2000 when "Soft OR" and "Soft System Methodology" made it to the specified keywords of the journal. Nevertheless, soft OR is considered very much a part of MS/OR at least outside of America where journals still dominate quantitative analysis models (Mingers, 2011; Ackermann, 2012).

CHAPTER 2
Problem Structuring Methods (PSM)

"The world that we have made as a result of the level of thinking we have done thus far creates problems that we cannot solve at the same level as they were created."

Albert Einstein

This chapter describes the definition of problem structuring methods (PSM), the origins as well as the characteristics according to various researchers in the field. The questions we want to answer are: What are PSM? What are their characteristics? What are PSM process, technology and product?

There is some confusion in literature about the methods that can be classified as PSM as different scientists include different methods in their works. The third section of this chapter identifies different PSM lists present in literature and the explicit and implicit criteria that have been used by different researchers in order to make these lists. The purpose of this list is to help the readers with the understanding of the boundary of PSM.

2.1 Unstructured/ Ill-structured problems

It is imperative to discuss the ideas and concept of unstructured problem in order to form a coherent understanding of the problems that can be addressed using Problem Structuring Methods. The wicked, mess, swamp or super-wicked problems described in previous sections provide us with the basic idea of complexity in unstructured problem situations encountered in daily life. Evans describes a problem as a difference between a present state and a desired state which can be positive, negative or unknown (Evans, 1991). Positive gap occurs when there is an opportunity to improve from present baseline, negative gap occurs when there is a drop in performance and the gap is unknown when a radical change in technology or in policy makes the set baseline as irrelevant.

Simon describes three different types of problem situations: well structured, ill structured and semi-structured (Simon, 1960). In his paper 'The Structure of an ill-structured Problem', Simon describes the criteria of a well-structured problem (Simon, 1973).

- There is a definite criterion for testing any proposed solution, and a mechanizable process for applying the criterion.
- There is at least one problem space in which can be represented the problem state, the

goal state, and all other states that may be reached, or considered, in the course of attempting a solution to the problem.

- Attainable state changes can be represented in a problem space, as transitions from given states to the states directly attainable from them.
- Any knowledge that the problem-solver can acquire about the problem can be represented in one or more problem spaces.
- If the actual problem involves acting upon the external world, the definition of state changes and the effects upon the state of applying any operator reflect with complete accuracy in one or more problem spaces the laws that govern the external world.
- All of these conditions hold in the strong sense that the basic processes postulated require only practicable amounts of computation, and the information postulated is effectively available to the processes (available with only practicable amounts of search).

In a nutshell, well-structured problems come with complete information, and are typically repetitive or routine. In a well-structured problem, the objectives are clear and the feasible alternative solutions are often obvious (Simon, 1960). On the other hand ill structured problems have characteristics completely opposite to well-structured problems. Ill-structured problems tend to be **complex, non-routine, and difficult to define**. Potential **alternative solutions**, objective(s) associated with solving these problems, and the relevant decision makers and stakeholders, are often not obvious. The data required to model the problem are usually not readily available. The characterizing features of ill-structured problems are (Ellspermann et al., 2007):

- The existence of several decision makers and stakeholders, each with their own viewpoint of the problem situation.
- Closely related to number one, the existence of multiple criteria, which are typically not known initially, which must be considered in the evaluation of proposed solutions.
- Large amounts of uncertainty associated with various aspects of the problem situation.
- The existence of an entire network of problems to which the original ill-structured problem is related.
- The fact that alternative solutions to the problem are not readily apparent.

> *"The existence of several decision makers and stakeholders usually will result in alternative preference structures over the identified set of performance*

> *measures. Hence, there typically must be some sort of compromise among the decision makers/ stakeholders as part of the problem structuring method"* (Ellspermann et al., 2007).

According to Rosenhead and Mingers (2001), following are the characteristics of unstructured problems:

- multiple actors,
- multiple perspectives,
- incommensurable and/or conflicting interests,
- important intangibles,
- Key uncertainties

Mingers summed these characteristics in a more general way as follows (Mingers, 2011):

- The "problem" itself is not well defined with agreed objectives such that efficient means to achieve the objectives can be constructed. Even non-optimizing methods such as critical path analysis, decision analysis or simulation could not be used.
- The situations all involve several interested parties whether they are departments within the organization, or cooperating (or conflicting) external bodies. These generally hold different perspectives about the problem situation.
- There are many uncertainties and often a lack of reliable (or indeed any) data (or other uncertainties like the interest level of participants, motivation etc)
- "Success" requires the generation of a degree of agreement among parties involved in undertaking particular courses of action, although agreement about the nature of the problem may then lead to more traditional OR activity. The process is primarily one of learning and negotiation rather than the technical solution of a problem.

(Gary, 1989) provided the following characteristics of ill-structured problem situation:

- the problems are ill-defined, or there is disagreement about how they should be defined
- the problems are often characterized by complexity and uncertainty
- existing processes for addressing the problems have proved insufficient and may even exacerbate them
- several stakeholders have a vested interest in the problems and are interdependent

- these stakeholders are not necessarily identified a priori or organized in any systematic way
- incremental or unilateral efforts to deal with the problems typically produce less than satisfactory results
- differing perspectives on the problems often lead to adversarial relationships and conflict among the stakeholders
- stakeholders may have different levels of expertise and different access to information about their problematic situations
- there may be a disparity of power resources for dealing with the problems among the stakeholders

2.2 Why is it necessary to structure the problem?

Research shows that structuring of an ill-structured problem is extremely important. It is the most critical step while addressing a complex, unstructured problem situation. Larson has said that *"70 percent of the value added of operations research is the correct framing and formulation of the problem"* (Horner, 2004). Problem structuring is a stepping stone to other aspects of problem solving process such as data collection, interviews, modeling etc. (Pidd, 1988). If a problem isn't structured properly or effectively, it can have negative consequences and drawbacks.

2.2.1 Solving the wrong problem

Mitroff & Featheringham proposed the idea of an error of third kind which means that if the problem hasn't been structured effectively, it will increase the probability of solving the wrong problem when more attention should have been placed on solving the right problem. Effective and proper problem structuring involves identifying the correct problem and defining it with the help of all actors. If this is not done properly, it will increase the probability of type three errors (Mitroff & Featheringham, 1974).

> *"It is a familiar and significant saying that a problem well put is half solved. To find out what the problem and problems are which a problematic situation presents to be inquired into, is to be well along in inquiry. To mistake the problem involved is to cause subsequent inquiry to be irrelevant or go astray."* (Dewey, 1998)

2.2.2 Incorrect definition of the problem

Problem definition is an important part of problem structuring. **"A well-defined problem is half solved"**. Similarly, Einstein said that if he had **one hour to solve a problem, he would spend 55 minutes to define the problem and 5 minutes to solve it**. One of the main usefulness of effective problem structuring is that it allows the correct definition and representation of a problem. If problem structuring is done ineffectively, it results in a very narrow definition of a problem and a limitation of alternatives (Watson, 1976).

> *"The initial representation or conceptualization of a problem is so crucial to its subsequent treatment that one is tempted to say that the most important as well as most difficult issue underlying the subject of problem solving is precisely 'the problem of how to represent problems.'"* (Mitroff and Featheringham, 1974).

2.2.3 Solving symptoms rather than root causes

Problem structuring, if done effectively, enables to identify the root cause of a problem and which can be tackled by decision makers. If problem structuring is ineffective, it leads to decision makers putting more attention to the symptoms rather than the root causes. This means that any solution or result achieved will only be temporary and problem can resurface again (Kepner and Tregoe, 1981).

2.3 Problem Structuring Methods (PSM)

Problem structuring methods (PSM) are used in the context of management science and operations research to construct useful representations of the situations and increase understanding about problems set within them. PSM focus on generating changed understandings of the problem situation by and between participants, so that they can reach agreement both on the nature of their shared problem and on commitments which will address it (Rosenhead and Mingers, 2001).These methods address the unstructured messy problems or problem situations. Journal of the Operational Research Society dedicated a special issue related to PSM and in the editorial they were defined as:

> *"... A collection of participatory modeling approaches that aim to support a diverse collection of actors in addressing a problematic situation of shared concern. The situation is normally characterized*

> *by high levels of complexity and uncertainty, where differing perspectives, conflicting priorities and prominent intangibles are the norm rather than the exception..."* (Shaw et. al, 2006)

Daellenbach and McNickle in their book *Management Science: Decision making through systems thinking*, provide an excellent definition of PSM.

> *"A branch of management science, based on systems thinking, that uses a non-mathematical or interpretive systems approach. PSM attempt to deal with the human aspects and soft facts of problem solving, usually calling for the active involvement of all stakeholders and aiming to bring about a shared understanding and a consensus agreement of what steps to follow for solving or resolving the issue(s)."* (Daellenbach and McNickle, 2005)

The fundamental configuration of PSM entails illustration of an idea or various notions in a pictorial or diagrammatical form (maps, pictures, graphs). These ideas can be generated by an individual or by a group. The resulting representation is investigated within the group by using PSMs promote the expansion of a superior understanding by members, to facilitate in communication and assisting the group to negotiate towards improvements so that the situation can be addressed.

> *"(Each problem structuring method) accommodates multiple alternative perspectives, can facilitate negotiating a joint agenda, functions through interaction and iteration, and generates ownership of the problem formulation and its action implications through transparency of representation".* (Rosenhead, 1996)

According to Mingers, the following are the *key characteristics of PSMs* (Mingers, 2011):

- The methods are not mathematical, but they are nevertheless structured and rigorous. They are based on qualitative and often diagrammatic modeling procedures. Obviously numerical information may be included, but not complex equations.
- They allow a range of distinctive views to be expressed and explored, and embrace multiple and conflicting objectives without collapsing them into a single, often financial, measure.
- They encourage the active *participation of stakeholders* in the modeling process, often through facilitated workshops of those affected by the problem. In order to encourage

participation, models should be transparent to participants. This is aided by the first point that they are generally non-mathematical.

- Significant *uncertainty* is expected and tolerated as is a lack of reliable quantitative data.
- They aim for exploration, learning and commitment rather than optimization.

Rosenhead and Mingers describe the classical characterization of PSMs based on the differences between classical/traditional paradigm of OR and the 'alternative' paradigm. The aspects of PSM highlighted are (Rosenhead & Mingers, 2001):

- Non-optimizing, seeking solutions which are acceptable on separate dimensions without trade-offs rather than formulating the problem in terms of a single, quantifiable objective.
- Reduced data demands, achieved by greater integration of hard and soft data with social judgments, thereby seeking to avoid problems of availability, reliability and credibility.
- Simplicity and transparency aimed at clarifying the terms of conflict
- Conceptualizing people as active subjects rather than treating them as passive objects
- Facilitating planning from the bottom up in contrast to an autocratic, hierarchically implemented process
- Accepting uncertainty and the need to address this through qualitative analyses and aiming to keep options open, rather than pre-taking decisions on the basis of expected probabilities

Daellenbach describes PSM while focusing on a process oriented baseline which gives us an idea of the nature of these methods in practice (Daellenbach, 1994).

- Focusing on structuring a problem situation, rather than on solving a problem
- Aiming to facilitate a dialogue between stakeholders in order to achieve greater shared perception of the problem situation, rather than to provide a decision aid to the decision maker
- Initially considering 'What' questions, such as: "what is the nature of the issue?"; "what are appropriate objectives given the differing worldviews of stakeholders?"; "which changes are systemically desirable and culturally feasible?" and only then "how these changes could be best achieved?"
- Seeking to elicit resolution of the problem through debate and negotiation between the stakeholders, rather than from the analyst

- Seeing the role of the "analyst" as facilitator and resource person who relies on the technical subject expertise of the stakeholders

In addition to these requirements, Rosenhead specified that PSMs should be iterative in nature which progresses between **"analysis of judgmental inputs and the application of judgment to analytic outputs"** (Rosenhead, 2006) and that PSM should support "partial commitments" in the sense that while each participant feels satisfied that there has been incremental progress with respect to his concerns, there is no constraint for **"…commitment to a comprehensive solution of all the interacting strands that make up the problematic situation"** (Rosenhead, 2006).

Each PSM has its own specific approach or method to deal with capture, structure and analysis of relevant material or data but what they share is a representation of the situation that will enable participants to clarify their predicament, converge on a potentially actionable mutual problem or issue within it, and agree commitments. Each PSM emphasizes on visual and qualitative representation of a problem involving high level of complexity and uncertainty. PSM according to (Rosenhead and Mingers, 2001):

> *"Accept as a fact that the most demanding and troubling task in formative decision systems is to decide what the problem is. There are too many factors; many of the relationships between them are unclear or are in dispute; the most important do not reduce naturally to quantified form; different stakeholders have different priorities. Problem structuring methods use models (often in the plural and with little or no quantification) to help mostly group decision-making—since it is rare for such issues to be resolved by single decision makers. The model representations are used to provide enough structure that those who must take responsibility for the consequences of the choices which are made, do so on a coherent basis and with sufficient confidence to make the necessary commitments."*

Furthermore,

> *"PSM realize their potential most fully in use with groups in work-shop format, That is, meeting without formal agenda or chairing but with a shared commitment to making progress to the issue at hand. Indeed, PSM have been called "wide-band group decision support systems," where "wideband" indicates their ability to handle problems that have not been pre-formulated and may have quite diverse structures."* (Rosenhead and Mingers, 2001)

The available technology and the intended product of PSM need to be explained in a better way. These characteristics are represented in Table 1 and explained in greater detail by (Cushman et. al, 2006).

Table 2.1
PSM process, technology and product (adapted from Rosenhead and Mingers, 2001)

PSM process	Group-based. Facilitated. Participative. Interactive. Iterative. Adaptable. Phased. Non-linear.
PSM technology	Model-based. Requisite. Diagrammatic/language-based. Reduced quantitative data requirements. Transparent/accessible. Low technology. Analysis of cause and effect relationships. Analysis of significant discrete options.
PSM products	Problem structure. Increased understanding. Accommodations of multiple positions and in power relations. Ownership of problem structure and of consequence of planned actions. Partial commitments. Learning.

2.3.1 PSM process

As already pointed out, the purpose of using PSMs is to facilitate *groups* in order to agree on a problematic situation they encounter. All the group members are encouraged to participate and exchange their understanding of the problem situation which is being structured. Because of this, PSM process is *participative* in the sense that group members are able to jointly construct the problem situation, make sense of it, arrive at a shared problem definition, and develop a portfolio of options relevant to the problem so defined (Rosenhead and Mingers 2001). This participatory process is usually *facilitated* by a researcher or consultant (Ackermann 1996).

Furthermore, it has also been mentioned that PSM process is *interactive* (Rosenhead and Mingers 2001as the interaction between participants is encouraged and also in the sense that the participants interact with the analysis. The interaction between participants and analysis reshapes and reforms the analysis which then transforms the discussion. Therefore, the PSM process is also *iterative* (Rosenhead and Mingers 2001), because the process is repeated until the problem situation is satisfactorily structured so that the group feels sufficiently confident in making commitments.

PSM allow the participants to distance themselves from previous commitments and bindings, effectively providing them with a certain degree of 'equivocality' or ambiguity with regards to their position during the PSM process (Eden and Ackermann, 2004). This allows the participants to change their position without destroying the social order in the group (Eden, 1992). Changing positions imply individuals 'changing their minds', i.e. changed beliefs, changed values and changes in the salience of particular issues or values (Eden, 1986). The consequence of this *adaptability* is that it becomes easier for participants to reconcile the position they eventually take both with principles and with past words and actions during a PSM process (Cushman et al, 2006).

Most PSM are organized into stages or modes and thus are *phased*. This 'phasedness' makes it possible for the users of the method to conclude without passing through all the modes that compose it, and still have a visible product which can be of use to them. Furthermore, the phases of the different PSM do not have to be followed in a linear sequence. Instead, PSM tend to operate in a *non-linear* fashion which makes it possible for the participants to cycle between the phases. As Eden (1992) argues, the characteristic non-linearity of the PSM process is a direct consequence of acknowledging that participants in a group decision making process will consider the practicality of possible actions at the same time as the problem is formulated.

2.3.2 PSM Technology

PSMs utilize a *model-based* technology. Due to this basic characteristic of modeling, PSM are assigned their unequivocal identity in management science. This sets them apart from other disciplines such as organizational development (Rothwell and Sullivan, 2005). PSM models offer stakeholders a 'transitional object' which is used in order to have a better understanding of the problem situation and to negotiate the future outcomes (De Geus 1988; Eden and Ackermann 2004).

The model-type in PSM are *requisite* (Phillips 1984). This means that the models contain sufficient knowledge and information to assist stakeholders and allow them to move forward in order to address the problem situation. Moreover, PSM models are in visual or *diagrammatical form*, and mostly use participants' own *language* rather than mathematics or quantitative data to represent the problem (Cushman et al., 2006). The leading supporters of PSM assert for the purpose of modeling in case of complex and ill-structured problem situations, only language provides the richness, clearness and transparency (Checkland 1981; Eden et al., 1983).

The diagrammatical and visual models developed in PSM are of particular value and importance to represent complexity to all the actors as they might find the traditional/classical models to be

unclear and difficult to comprehend (Eden and Ackermann 2004; Rosenhead and Mingers 2001). Theoretically, PSM models should represent everything where nothing is hidden which makes them *transparent* (i.e. easy to understand) and *accessible* (i.e. simple to use).

The tools and resources required for PSM modeling are extremely less: enough space for participants to gather and move around freely and a set of movable chairs gathered around the facilitator; large sheets of paper; some adhesive material to fix the paper on wall or on a board; and multi-colored markers in order to make models and any other thing that might prove useful (Eden 1990; Hickling 1990). In fact, these characteristics of transparency, accessibility and limited resources required make the PSM *low technology* approaches. This implies that PSM modeling is technically a comparatively straightforward activity conducted in a workshop format, and one which does not necessarily require software to support it (Ackermann and Eden 1994). Some PSMs do, however, use software to support their modeling processes, which allows them to operate as 'group decision support systems' (Ackermann 1990; Eden 1992; Phillips 1989).

Models in PSM are used to graphically represent, among other things, relationships between concepts, activities or stakeholders, relationships of similarity or influence, and relationships between options. Especially significant is the modeling of cause and effect relationships through which the different elements that make up the problem situation are identified. By modeling cause and effect relationships, PSM models are thought to help participants to 'look beneath the surface' to establish problem structure.

As Rosenhead and Mingers (2001) point out, the purpose of PSM is not to identify a single optimal solution. This means that the entire 'solution space' is in principle of interest during the PSM modeling activity. However, because the set of all possible solutions would be unmanageable large, PSM models limit their scope at any time to a set of *discrete 'solutions'* or *options* for action selected using different screening procedures (e.g. by filtering out internal incompatibilities between options or eliminating them through dominance; by using thresholds of acceptable performance; by bundling into coherent packages representing contrasting priorities, etc) (Rosenhead and Mingers 2001). By concentrating on a few significant discrete options (which may change during the analysis), PSM models seek to help participants to handle the systemic complexity of their problem situation.

Several products have been claimed to be the result of the use by groups of PSMs processes and technology. Some of these products will be tangible outcomes of the PSM process, whilst others will be less visible but valuable in their own right (Friend and Hickling 2005).

2.3.3 PSM Products

The model built using PSM is obviously the main product of which incorporates the *problem structure*. The PSM model acts as a 'transitional object' (De Geus 1988) or 'negotiative device' (Eden 1988), and is thought to facilitate the achievement of a number of invisible products. First, it is argued that by allowing the mutual exploration of the problem structure as portrayed by the model, PSM enable the *accommodation of multiple and differing positions* (Checkland 1981). The argument is based on the notion that situations characterized by complexity, uncertainty and conflict will commonly require participants to adjust their positions and/or expectations to take into consideration the possible objectives and strategies of others (Rosenhead 1996; Rosenhead and Mingers 2001).
Accommodations between actors may also require coalition forming (Eden 1986; Eden and Ackerman 2001), which may produce a *shift in power relations* during the PSM process (Eden 1992). Second, the analysis of cause and effects relationships embedded in the PSM model is thought to give participants an *increased understanding* of the problem situation, of organizational processes and cultures, and of others' beliefs and values. Such increased understanding is taken to be conducive to *learning* (Checkland 1981; Eden and Ackermann 1998; Friend and Hickling 2005), Third, it is argued that actors' active participation in the analysis and modeling process produces strong *ownership* of the problem formulation, and of the actions to be taken, as well as acceptance of responsibility for the consequences of the actions taken (Rosenhead and Mingers 2001).

A visible PSM product which, it is argued, results from the accommodations, increased understanding, and ownership achieved during the PSM process takes the form of a set of *partial commitments*, and which are usually expressed as an action plan or 'commitment package' (Friend and Hickling 2005). Action plans can contain a mix of espoused or recommended decisions, policies or research explorations, and may or may not include supporting argumentation derived from the PSM model. The development of partial commitments is based on the notion that the only way to make progress in swamp conditions is by adopting an incremental approach and thus working on a less comprehensive solution (Eden and Ackermann 1998; Friend 2001; Rosenhead and Mingers 2001).

2.4 Problem Structuring Methods in Literature

In this section, we will highlight some of the works in literature where a list of PSMs has been presented and will try to identify the explicit and implicit criterias presented by the authors in order to choose their lists.

2.4.1 Rosenhead Rational Analysis for a Problematic World (1989)

Rosenhead's book was one of the first books that described theoretical and practical chapters related to PSMs in the form of a list. Rational Analysis for a Problematic World was the book which formally defined the field in the UK, and acted as a catalyst for wider recognition of PSMs, their application and their merits. Rosenhead put forward the idea of an alternative paradigm related to decision making (which has been discussed in the first chapter of the thesis report). The characteristics of dominant paradigm and alternative paradigm have been mentioned in the Table 1.1 and 1.2 in previous chapter.

Rosenhead explained six PSMs methods which were characterized by lack of optimality, transparency, reduced data demands, clarification of conflict and actors as active subjects. These six PSMs are: **SSM, SODA, SCA, Robustness Analysis, Metagame Analysis and Hypergame Perspective**. All the PSMs mentioned by Rosenhead conform to the six dimensions of an alternative paradigm of decision making. However, some approaches conform to one characteristic more than others but the basic idea and general conformity with all the characteristics is there (Rosenhead, 1989) for example:

- *Uncertainty* and the preservation of options are most explicit in Strategic Choice Approach (SCA) and Robustness Analysis but none of the other approaches assumes a certain future which is to be planned for.

- *Explicit clarification of conflict* is limited to Metagame and Hypergame perspectives but other methods make use of more transparent simpler parent models.

- *Participants as active subjects* is more prominent in approaches based on group working (SSM, SCA, SODA) but other approaches offer substantial scope for active participation through transparency of presentation, focus on immediate commitment and so on.

- *Optimality* is absent from all of the PSMs described by Rosenhead so is the need for trade-offs or single objectives. SCA and Robustness Analysis, in particular, help to identify a range of acceptable schemes while Hypergame and Metagame Analyses employ game-theoretic logic to form an understanding of human behavior in the decision making process.

- *Data requirements* in all of the PSMs are much reduced. This is partly because of the strategic domain of the application and in part because of the role of PSMs as assisting

rather than placing judgment.

- *Bottom-up planning* is addressed directly only by SODA through the combination of individual cognitive maps into single strategic map. Other approaches use bottom-up planning more indirectly through their user-friendly transparency but not through any particular formulations.

This is summarized in Table 2.2 where the characteristics of PSMs have been compared with the six Problem Structuring Methods explained in Rosenhead's book. As explained earlier, some criterias are explicitly addressed by some PSMs while others are addressed implicitly or indirectly. All the PSMs fulfill the criteria put forward by Rosenhead i-e, the six characteristics. Rosenhead put forward these methods as an alternative to the orthodox and classical paradigm where the methods are mainly problem SOLVING methods which start with concrete objectives from which concrete decision options are then deduced. Problem structuring methods, however, start with decision options available to one or more participants in the problematic situation. These decision options are analyzed for feasibility, compatibility etc, which make use of preference information but without the assumption of any dominating objectives. This provides the conceptual freedom to develop the methodologies for use in bottom-up planning (Rosenhead, 1989).

Table 2.2
Comparison of PSM with criteria (Adapted from Rosenhead, 1989)

PSM / Criteria	SODA	SSM	SCA	Robustness Analysis	Metagame	Hypergame
Uncertainty	Implicit	Implicit	Explicit	Explicit	Implicit	Implicit
Conflict Clarification	Implicit	Implicit	Implicit	Implicit	Explicit	Explicit
Active subjects	Explicit	Explicit	Explicit	Implicit	Implicit	Implicit
Optimality (absence)	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit
Data requirements (Min)	Explicit	Explicit	Explicit	Explicit	Explicit	Explicit
Bottom-up planning	Explicit	Implicit	Implicit	Implicit	Implicit	Implicit

2.4.2 Rosenhead and Minger's Rational Analysis for a Problematic World Revisited (2001)

This is the second edition of Rosenhead's book that was published in 1989. After the first book, there had been so many advances in the field of Problem structuring methods or soft OR and these have been covered in this new book by Rosenhead and Mingers. The criteria for the selection of the methods are again the alternative paradigm characteristics mentioned in the previous section.

This book discusses five methodologies in detail: **SODA, SSM, SCA, Robustness Analysis and Drama theory**. Metagame and Hypergame analysis have been replaced by drama theory. There is another chapter that gives very short description of related methods such as **VSM, System Dynamics and Decision Analysis**. Another addition to the previous book is the introduction of Multimethodology which is the combination of two or more approaches in order to deal with a particular problem situation.

2.4.3 Flood and Jackson's Creative Problem Solving: Total System Intervention (1991)

Jackson and Flood assert that real world problems are far-too complex and have high uncertainty that they cannot be solved by just one approach. Flood and Jackson's book lucidly describes their own particular approach to problem solving using different systems methodologies. They argue that the diversity of systems-based approaches in existence represents a strength, (rather than a fragmentation and a weakness), when linked with a framework for choosing between them in particular problem situations (including combining or alternating methods where appropriate). They call their framework 'Total Systems Intervention' or TSI. They propose a system of system methodologies that help managers to choose a method depending on the type of problem they face.

Jackson used 'critical' approach to address the inabilities of hard and soft methods; most important of which was their insufficient attention to power struggles that may arise in a consensual environment. System of systems methodologies (SOSM) was deployed by Jackson to create a categorization of systems methodologies that would allow for their complementary use in specified problem situations (Jackson, 1990). The main consideration in this approach is to assign a particular methodology for a specific problem situation. SOSM provides a matrix for classifying systems methods on two dimensions: one, the level of complexity of the problem situation (simple or complex), and the other dimension involves the classification of participants. Stakeholders are differentiated on the base of their common purpose. They are defined in a much better way in Table 2.3.

This process was called Total System Intervention which stands for the practical procedure of methodology choice and implementation that Flood and Jackson (1991) proposed on the basis of the SOSM. The aim is to provide a meta-methodology for methodology choice and

implementation. So Jackson proposed an understanding of the level of relationships between participants. Problem can be simple or complex so Flood and Jackson combined these dimensions to create a system of system methodologies for problem contexts (Table 2.4).

Table 2.3
Classification of types of opinions and participants (Flood and Jackson, 1991)

	Unitary	**Pluralist**	**Coercive**
Interests	Common	Basic Compatibility	No common interests
Values/Beliefs	Compatible	Slight divergence	Conflict
Ends and Means	Agreed upon	Compromise	Don't agree, compromise impossible
Decision making	Everyone involved	Everyone involved	Force others to accept
Objectives	Agreed upon	Agreed upon	No agreement

Table 2.4
An "ideal type" grouping of the problem contexts (Flood and Jackson, 1991)

SYSTEMS \ PARTICIPANTS	UNITARY	PLURALIST	COERCIVE
SIMPLE	Simple–Unitary	Simple–Pluralist	Simple–Coercive
COMPLEX	Complex–Unitary	Complex–Pluralist	Complex–Coercive

Flood and Jackson assigned different methods into these six cells as shown in Figure 2.1.

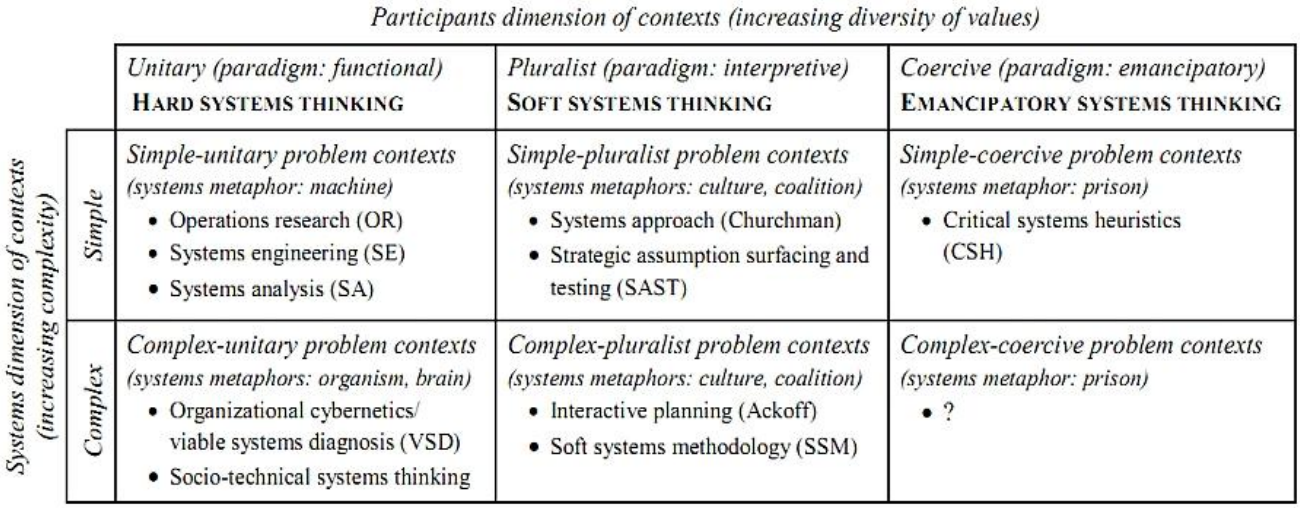


Figure 2.1: The extended system of systems methodologies (SOSM)
(Source: Flood and Jackson, 1991)

In the book, Flood and Jackson elaborate on System Dynamics, VSD, SAST, Interactive Planning, SSM and CSH. The authors explain each method and make it much easier for the readers to understand them because the methods are clearly presented theoretically practically in form of case studies. As can be clearly seen, the criteria of making the matrix for grouping different methodologies are the system of system methodologies (SOSM).

To support methodology choice in practice, the SOSM still needed to be embedded in a methodology properly speaking, that is, a framework that would guide practitioners in asking relevant questions and proceeding systematically. This is what total systems intervention (TSI), a name adopted in 1991, is all about. It stands for the practical procedure of methodology choice and implementation that Flood and Jackson (1991) proposed on the basis of the SOSM. The aim is to provide a meta-methodology for methodology choice and implementation. The procedure may be employed in a linear or iterative way. It consisted of three phases labeled creativity, choice, and implementation (Table 2.5).

The *creativity* phase is intended to encourage consideration of what alternative systems paradigms and root metaphors might mean for thinking about a problem context at hand, so that a dominant metaphor can be identified as most adequate, that is, in effect, preference can be given to either a hard (functionalist) or a soft (interpretive) or critical (emancipatory) orientation.

In the *choice* and *implementation* phases, a conforming particular systems methodology should then be chosen based on the SOSM and used to implement specific change proposals.

Table 2.5
the meta-methodology of TSI: Standard phases of methodology choice and use (Source: Flood and Jackson, 1991)

Phase	Activity/aim
(1) CREATIVITY	
Task	To identify major aims and issues of the problem context.
Tools	Use of different metaphors and paradigms to gain different perspectives.
Outcome	Appreciation of dominant and dependent metaphors/ paradigms and related issues.
(2) CHOICE	
Task	To choose appropriate systems methodologies and methods.
Tools	Use of SOSM to reveal strengths and weaknesses of methodologies and methods.
Outcome	Choice of dominant and dependent systems methodologies and methods.
(3) IMPLEMENTATION	
Task	To arrive at and implement specific positive change proposals.
Tools	Systems methodologies and methods used properly according to the logic of TSI/CH.
Outcome	Relevant change according to the concerns of the different paradigms.

Although this book is extremely important as can be seen by the number of citations it has received (1390), but there are some critisms levelled towards it as well. The first issue is the grouping of Operations Research in the simple-unitary problem context which implies that the definition of problem is very simple and all the stakeholders agree about objectives. However, as has been discussed, real life problems addressed by Operations Research are complex and ill-structured. This leads to a confusion among readers. If the terminology used had been 'traditional OR' it would have been more acceptable.

Another argument that can be put forward can be towards the system of system methodologies. Sometimes the problems are not known or there are some stakeholders fail to admit that there is a problem. In such a situation, you cannot group the methodologies in a structured way as Flood and Jackson have. Certain problem situtaions simply cannot fit neatly into cells of the matrix.

2.4.4 Daellenbach extension of Jackson's Idea

Daellenbach (2001) extended the idea of Jackson and introduced two complexities (technical and social). Technical complexity is associated with the physical, mathematical, or computational nature of the problem whereas human/social complexity is associated with the interrelationships

between the stakeholders. These dimensions (technical complexity, social complexity and diversity of views allows us to classify three main streams of MS/OR as shown in Figure 2.2

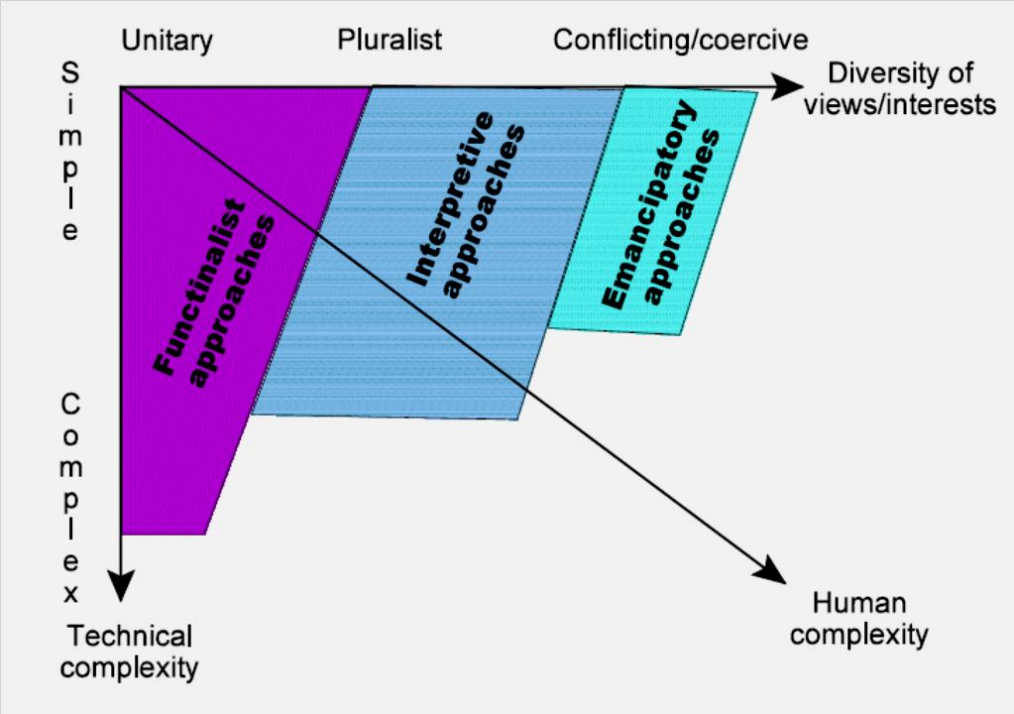


Figure 2.2: Problem situation classification and systems approaches (Daellenbach, 2001)

2.4.4.1 Functionalist System Approaches

These approaches assume that systems are 'objective' aspects of reality, largely independent of the observer, i.e., different observers would basically see the same system and share the same goals or objectives. Note that this does not imply that different observers and modelers may not draw the system boundaries differently or select a different degree of resolution to model the system. Functionalist approaches have seen successful applications in problem situations that may have considerable technical complexity, but in general can only cope with low human complexity and low to medium divergence of interests (i.e. multiple objectives, in contrast to values).

In general, these approaches are based on the following assumptions about the problem situation:

- the problem has been clearly defined, the objectives of the decision maker(s) are known and there exist criteria to ascertain when they have been achieved; the alternative courses of action are specified, either as a list of options or sets of decision

variables; the constraints on the decision choices are known; and all input data needed are available;

- the problem is relatively well structured, meaning that the relationships between the variables are tractable; they can be expressed in quantitative form; and the computational effort for determining the optimal solution is economically feasible;
- the problem can be sufficiently well insulated from its wider system of interest;
- the problem is of a technical nature, largely devoid of human aspects; and
- The decision maker can enforce implementation of the solution.

Functionalist System Methodologies based on these characteristics include **MCDA, System Dynamics, linear programming and all the traditional MS/OR methods.** These approaches involve the use of quantitative approaches in the form of spreadsheets, computer simulations, statistical analysis, or potentially large mathematical models and optimization techniques. They have been successful to deal with highly complex physical systemic relationships. In today's world, few human activities in all walks of life are not touched in one way or another by the results of projects involving hard OR.

2.4.4.2 Interpretive systems approaches

These approaches adopt a subjectivist approach to systems thinking. The system defined for a given problem situation reflects the observer's *world view* (i.e., the colored glasses used to interpret the world, based on her or his social and cultural background, education, experience, and personal values). It is not assumed to exist in exactly this form in reality, but is seen as a personal conceptualization of what the observer views as a useful and convenient representation of interrelationships in view of learning more about the behavior of the system. Although interpretive approaches allow a certain divergence of interests and views, they assume there is a sufficient sharing of interests that the various stakeholders consider it in their interest to cooperate. Interpretative approaches can cope with a fair degree of human complexity and diversity of interests and values, but have greater difficulty to deal with technical complexity.

Interpretive systems approaches address problem situations which are messy, ill-structured, and ill-defined in terms of their human components and relationships, not independent of the people involved, in other words, where different stakeholders with different world views have different, possibly conflicting perceptions about the problem situation and its major issues; where there may be no agreement about the appropriate objectives, or even the set of possible actions; and where it may be meaningless to talk about optimization, since a resolution usually involves a

comprise, but where there are sufficiently shared values and interests to cooperate. They are characterized by

- structuring the problem situation, rather than by problem solving;
- facilitating dialogue between the various stakeholders with the aim of achieving a greater degree of shared perceptions of the problem situation, rather than providing a decision aid to the decision maker;
- 'What' questions, more than by 'how' questions, i.e,

  'what is the nature of the issue?';

  'what are appropriate objectives?' given the various world views of the stakeholders;

  'what is the appropriate definition of the system for the issue considered?'

  'which changes are systemically desirable and culturally feasible?'

  and only then

  'how are these changes best brought about?'
- eliciting the resolution of the problem through debate and negotiation between the stakeholders, rather than from the analyst; and
- Changing the role of the 'problem analyst' to one of becoming a facilitator and resource person who relies on the technical subject expertise of the stakeholders.

Methods include **Hypergame analysis, metagame analysis**, **interactive management**, **robustness analysis**, **soft systems methodology**, **strategic assumption surfacing and testing**, **strategic choice approach, strategic options development and analysis, drama theory.**

They all have one thing in common. They start out seeking to attain a reasonably comprehensive view of the issue(s) within its wider context, although most recognize that true comprehensiveness is not impossible, nor may it be needed to get to a workable resolution of the 'problem'. This initial analysis is then structured in various ways, e.g., by uncovering uncertainties about values, choices, and the environment, and identifying clusters of highly connected aspects. The main aim at this stage is to gain a shared understanding and mutual appreciation of the issues, including personal world views and objectives. The aim is not necessarily to bring about a convergence of views, but in practice at least a partial convergence is likely to emerge from this process. The ultimate aim is to get a commitment for action. Most approaches iterate through or between various modes of working. Several methods use specialized software to aid in the structuring process and/or the exploration of the combination of choices available. Most require a facilitator, with sufficient training and experience in the method and with good interpersonal and negotiation skills.

2.4.4.3 Emancipatory systems approaches

These approaches also take a subjectivist view of systems. However, the various stakeholders may see radically different relevant systems with different values and *boundary judgments* (i.e., justifications of what is relevant and what is not), and they may be in a conflicting or confrontational relationship with each other and possibly unequal in terms of their *power* over the situation, with some being potentially in a victim role. These approaches have difficulties to cope with both high technical and human complexity. 'Resolutions' of such problem situations may involve reforms and changes in the current social order. Their domain of application is mainly in public policy issues.

Emancipatory systems approaches sit (somewhat uncomfortably) in the overlap between sociology, organization theory, systems thinking and by extension management science. These approaches claim that functionalist and interpretive systems approaches tend to accept existing inequalities of wealth, status, power, authority, gender, race, and sexual orientation, and largely neglect those views and interests of those who have no voice in the decision making process, but who suffer the consequences, including future generations, non-human species, and the environment. In this way they serve to support, buttress and legitimize the status quo. Emancipatory systems approaches aim to identify such inequalities and neglect and promote radical change to emancipate and liberate the deprived majority and create a civil society. Much of the work in community OR has been along that nature. They are seen essential to deal effectively and equitably with issues, such as poverty, health care, and the environment, etc.

In contrast the functionalist and interpretive approach, emancipatory systems thinking has remained largely on a philosophical and polemic level. The exception is Ulrich's **Critical Systems Heuristics** (Ulrich, 2000) which provides a systematic philosophical foundation and a practical framework for the kind of *critical systems thinking* needed to create a civil society. Since any systems analysis can never be completely comprehensive and furthermore is affected by the personal world views of the stakeholders with the power of decision making, critical systems heuristics provides a methodology for systematic critique for boundary judgments that are and need to be made for sound professional practice, whatever importance may be attached to emancipatory issues.

2.4.5 Operational Research and Systems: The Systematic Nature of Operational Research by Paul Keys (1991)

This book by Paul Keys mainly deals with three main themes: the theory-practice relationship in OR and systems, the role of scientific method in OR and systems and the extent to which either Operational Research or systems are embedded within the other (Keys, 1991).

After describing some hard system methodologies, the author reiterates the need of other methodologies beyond the boundary of hard system in order to address the drawbacks and to overcome the restrictions in hard system methodologies. According to Keys, the boundaries of hard system thinking are defined by **complexity of the problem situation, the differences in the worldview taken by various actors and the power relations that characterize a situation**. If the complexity of problem situation, the complexity of varying perspectives and the level of power struggles are negligible, hard system problem solving methods can be utilized. Keys describes various methods; each of them specific to a particular dimension. Most of the PSMs have been included in the methods required to address the complexity of varying perspectives (pluralism) but not under the banner of problem structuring methods. They have been describes as alternative methods beyond the boundary of hard system thinking. The criteria of selection of methods are the boundary definition of hard system thinking. In the next section, all of the methods provided by (Keys, 1991) have been mentioned.

2.4.5.1 Tools for tackling complexity

Complexity, as already discussed in the beginning of this chapter, is an attribute related with situations when they are believed to be difficult to comprehend. Size of the problem, behavioral processes and dynamics each contribute towards creating potential complex situations. The main focus of Keys in selection of tools in this section is on 'the ways the system ideas can be used to inform methods of addressing situations which appear to be complex' (Keys, 1991).

According to Keys, there are two streams which can be utilized in order to address a problem situation. One approach is appropriate when the complexity in problem rules out quantitative analysis but some structure can be identified to construct a qualitative model. This model can then be further elaborated and explored in order to increase the understanding of the situation and, possibly, to allow construction of a quantitative model finally. One such approach identified by Keys is **Qualitative System Dynamics (QSD)**. The alternative stream is to accept the complexity as there is no possible way of achieving a reduction in uncertainty. In such a case it becomes necessary to create mechanisms and processes that allow adaptation to future unexpected change to take place and to encourage learning from these experiences. Keys identified two methods that guide the design and implementation of flexible, responsive structures: **Sociotechnical System Design (STSD)** and **management cybernetics (MC)**.

2.4.5.2 Tools for tackling pluralism

Pluralism arises when there are varying viewpoints of individuals and some of the viewpoints are not dominated by exercise of power by some of these individuals. In some complex cases, each actor or group of actors brings their own viewpoints and their own specific objectives. These

problem situations cannot be addressed by using hard system methodologies, which require a consensus between the actors as far as the objectives are concerned. So, methodologies are required that that can engineer an agreement over what objectives are to be pursued.
A necessary to achieve this aim is to use a presentation which depicts different perceptions and viewpoints of a situation without any bias or prejudice. This presentation has to be transparent and should be understood by all the actors and should enable them to understand the viewpoint of other actors. Keys also mentions the relationship between complexity and pluralism that usually in complex situation there are different viewpoints and no clear definitions. This complexity gives rise to pluralism and vice versa. Therefore, methodologies that are capable of handling pluralism must also be able to handle complexity. The methodologies mentioned by Keys to deal with pluralism are: **SAST, SODA, SCA, Interactive Planning and SSM.**

2.4.5.3 Tools for tackling power relations

Unlike pluralism, there exist some problem situations in which there in a superiority of an individual or a group over others involved so it might lead to the acceptance of a viewpoint that isn't acceptable by all actors involved. The approaches identified by Keys in the previous section are unable to account for the bias due to power and there should be a means to negate the biasing effect of power prior to the use of any of these methodologies (Jackson, 1982). This means that there must be an environment conducive for open debate in such a way that the agreements made cannot be altered by subsequent use of power. Keys identified one such approach developed by Ulrich: **Critical System Heuristics (CSH).**

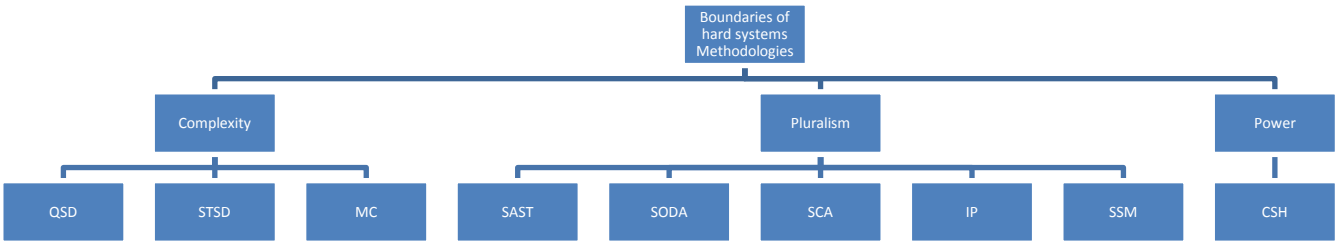


Figure 2.3: Tools to handle drawbacks of hard system methodologies (Adapted from Keys, 1991)

2.5 Criteria of PSM for thesis

As can be seen by the list of PSM present in literature in the previous section, there is a difference of selection of methods in the umbrella term of PSM. Different authors have used different criteria in creating their lists which have been presented. One of the objectives of this thesis is to provide a functional definition of PSM and highlight the criteria and the differential characteristics in order to define the boundary of PSM in a better way and also to make clear the differences between PSM and other similar methods. Some of these characteristics are presented in the Table 2.5.

Table 2.6
PSM Criteria/ Differential Characteristics

PSM Differential Characteristics	Participatory Modeling Approach
	Use of model as a transitional object
	Negotiated understanding of problem
	Increased productivity and attention to the facilitation of the group process
	Transparency
	Adaptability
	Accessibility
	Interactive and Iterative process

PSM are utilized in the case of *ill-structured, messy problem situations* that have been explained in previous chapter. PSM are similar to each other in regards to *using a model as a transitional object* (Eden and Sims, 1979). PSM are used to address unstructured problem situations involving a large number of stakeholders. Participatory Modeling feature of PSM is an effective way to deal with collective decision-making processes. *PSM are participatory modeling approaches* that work on the rationale that by gathering and integrating a variety of viewpoints belonging to all the actors involved, a collective vision of the problem situation can be established and effectively addressed. This aspect of participatory modeling is extremely useful as far as integrating different sources of knowledge is concerned. Moreover, it is an effective way of representing reality and exploring a diversity of problems. Another important function of these participative modeling approaches is to form collaborative relationships and increases the commitment levels of the actors involved in decision-making process (Siebenhuner and Barth, 2005).

The main reason of using PSM is to form a coherent and *negotiated understanding of a problem* without the purpose of 'solving' the problem (Rosenhead, 1989). They are most significantly not intended to lead to optimal solutions, but rather use models designed to facilitate negotiation and agreement. Thus, although each of the models is "constructed through the use of a body of formalisms (ensuring a consistent model building process) there is enough equivocal (or fuzziness) to 'oil the wheels' of participants shifting and changing their position" (Eden and

Ackermann, 2006). The models of PSM therefore play a key role in driving the process of negotiation towards agreement through discussion and the development of a common understanding.

Each of the problem structuring methods is concerned with *increasing the overall productivity of group processes*. Here, the underlying presumption is that increased and more equal participation from members of a group is likely to be helpful in constructing better agreements, and agreements that are more likely to be implemented (Eden and Ackermann, 2006). Consequently and quite naturally, in the methods' consideration of productivity there is a concern to have processes for managing the resultant complexity that derives from multiple perspectives, rather than reducing it. The attention to complexity seeks to avoid errors of the third kind−solving 'the wrong problem when one should have solved the right problem' (Mitroff and Featheringham, 1974) as well as ensuring both procedural justice (Kim and Mauborgne, 1995) and procedural rationality.

PSM share a concern for designing a method that includes explicitly paying attention to the *facilitation of effective group processes*, with some account for the power and politics within organizational settings. This is to recognize that it is not only natural for different people to have different perspectives on a problem, but also that organizations are designed to encourage this. Accommodations between actors may also require coalition forming (Eden, 1986; Eden and Ackerman, 2001), which may produce a shift in power relations during the PSM process (Eden, 1992).

The *analyst acts as a facilitator* in PSM and there is an *appreciation of the significance of facilitation skills* in enabling effective model building, and reaching agreements. These are craft skills demanding many different roles for the operation researcher (Ackermann, 1996; Andersen and Richardson, 1997). These roles include (i) the ability to manage both process skills as well as content skills, and (ii) having sufficient flexibility and knowledge of the method to be able cycle between different stages of the methods to meet the group's needs (rather than follow a simple linear process).

The diagrammatical and visual models developed in PSM are of particular value and importance to represent complexity to all the actors as they might find the traditional/classical models to be unclear and difficult to comprehend (Eden and Ackermann, 2004; Rosenhead and Mingers, 2001). Theoretically, PSM models should represent everything where nothing is hidden which makes them *transparent* (i.e. easy to understand) and *accessible* (i.e. simple to use).

Other common features in PSM concern the process of the engagement through which analysis assists decision making. This process is *participative and interactive*. Little or nothing happens in back rooms or black boxes; those who must take or recommend decisions are participants in or executants of the analysis. The purpose of the analysis is to elicit relevant knowledge and to reflect it back in structured form in an *iterative process* of problem construction. Typically PSMs

operate nonlinearly, switching freely between different modes or phases of the method in response to the dynamics of group discussion. Outputs may be visible (recommendations, plans, policies) or invisible (changed appreciations, shared values, and better working relations).

Each member of the PSM family incorporates as a core element the explicit modeling of cause-effect relationships. This gives PSM their unambiguous operational research identity (Rosenhead, 1996). It distinguishes them, for example, from non-OR modes of group working, such as organizational development. PSM can also be distinguished from other OR approaches that purport to tackle messy, ambitious problems (for example, the analytic hierarchy process). PSM are distinctive in their transparency of method, their restricted mathematization, and their focus on supporting judgment rather than representing it. These limits are imprecise and arguable: approaches developed for other or broader purposes (for example, spreadsheet models) can be used in a similar spirit (Rosenhead, 1996).

> *"(Each problem structuring method) accommodates multiple alternative perspectives, can facilitate negotiating a joint agenda, functions through interaction and iteration, and generates ownership of the problem formulation and its action implications through transparency of representation"* (Rosenhead, 1996).

PSM provide an approach employing representation of relationships, symbolic manipulation, and limited quantification within a systematic framework. For the purpose of thesis **SSM, SODA, SCA, Robustness analysis, SAST and drama theory** completely adhere to the characteristics mentioned. All of these methods are participatory modeling approaches used to address unstructured, messy problem situations and aim to form a negotiated understanding of the problem situation with the help of a facilitator. Methods like MCDA, SWOT, System Dynamics, CSH, scenario planning and others can also be used for the purpose of structuring and can be considered as *"tools for structuring"* if the requirement is to just structure the problem. For example an article published in European Journal of Decision Process highlights that the structuring phase in an MCDA intervention or system dynamics should be seen as a PSM (Slotte and Hämäläinen, 2003). It depends on the familiarity of method to the user or the way it is used that will make it a part of soft methods or not. If the purpose is to structure the problem in a participative environment with an explicit pictorial representation (in form of maps, diagram), then it might be considered a part of soft methods. The purpose of categorization of PSM is that readers can have a better understanding about the characteristics of the methods. It ultimately depends on the way the methods are used, that will categorize it as a hard or soft method.

Belton and Stewart categorize PSM based on the use of methods. They argue that some PSM are more generally applicable to problem situations while some methods are more focused. *General PSM* can be used to surface ideas and structure thinking with respect to any broadly defined issue, and, as a consequence, the most widely known and applied. *Focused PSM* such as

Robustness Analysis has a particular focus on consideration of uncertainty about the future and Drama Theory on the tensions underlying the potential for cooperation or conflict between multiple parties. General PSM includes SODA, SSM and SCA whereas focused PSM include Robustness Analysis and Drama theory (Belton and Stewart, 2002).

Finally, we compare our list of PSM with the characteristics that we have mentioned. As can be seen in the table 2.7, SODA, SCA, SSM, Robustness Analysis (RA), Drama Theory and SAST completely fulfill the characteristics. However, MCDA and system dynamics are more complicated. They can be used as participatory modeling approaches in order to have a thorough understanding of the problem situation but still in most of the cases in literature, they are employed in well structured problem situations. This doesn't mean that they cannot be used for complex problems but as we demonstrate in next chapter, now they are integrated with other soft methods. These methods can also be used to form a negotiated understanding of the problem. Critical System Heuristics (CSH) is another method that resembles PSM and is specifically developed for use in case of wide range of differences of opinions in intervention process. It can be used as a modeling approach as well as having a negotiated understanding of the problem situation.

Table 2.7
Cross reference of methods with characteristics

Criteria \ Method	**SODA**	**SSM**	**SCA**	RA	**Drama Theory**	SAST	**MCDA**	**SWOT**	SD	CSH
Participatory Modeling Approach	✓	✓	✓	✓	✓	✓	*	✗	*	*
Use of model as a transitional object	✓	✓	✓	✓	✓	✓	*	*	*	*
Negotiated understanding of problem	✓	✓	✓	✓	✓	✓	*	✗	*	✓
Increased productivity and attention to the facilitation of the group process	✓	✓	✓	✓	✓	✓	*	✗	*	✓
Transparency	✓	✓	✓	✓	✓	✓	*	*	*	✓
Adaptability	✓	✓	✓	✓	✓	✓	*	*	*	✓

2.6 Description of PSM

2.6.1 Soft System Methodology (SSM)

Soft systems methodology (SSM) is a problem structuring method for system redesign (Mingers, 2011). Participants build ideal-type conceptual models (CMs), one for each relevant world view. They compare them with perceptions of the existing system in order to generate debate about what changes are culturally feasible and systemically desirable. A description of SSM is that it is ‘‘the analysis of complex situations where there are divergent views about the definition of the system’’ and that the ‘‘approach uses the notion of a ‘system’ as an interrogative device that will enable debate amongst concerned parties’’ (Reynolds & Holwell, 2002).

Peter Checkland developed the fundamentals of soft system methodology (SSM) during his detailed work on industrial projects as a Professor Lancaster University (Checkland, 1981; Mingers, 2000). He saw his task as taking traditional, hard systems engineering methodologies, e.g., (Hall, 1962) , and trans- forming them to be able to deal with the humanness of human beings, highlighting the importance of irrationality, creativity and values (Checkland, 1970). Intellectually, SSM draws on the work of (Churchman, 1971) on dialectical inquiry, (Vickers, 1968) on social processes and, more generally, interpretive sociology. Indeed, Churchman’s early paper with Scheinblatt, considering the relationship between OR analyst and manager as one of ‘‘mutual understanding’’, foreshadowed Soft OR orientation (Churchman & Schainblatt, 1965).

In brief overview, the developed form of SSM involves the following stages:

- Discover as much as possible about the problem situation, especially its history, the nature of the engagement and possible issues, the prevailing culture and the power and politics (rich pictures, analyses)
- Develop systemic models of purposeful activity, which explicitly embody particular viewpoints or perspectives relevant to the situation (Weltanschauung). Express these in terms of root definitions and conceptual activity models.
- Use the models as a way of questioning and exploring the situation to structure a debate between involved parties about desirable and feasible changes.
- Gain agreement on changes to the situation, which the different perspectives or worldviews could accommodate.

2.6.2 Strategic Options Development and Analysis (SODA)

Strategic options development and analysis (SODA) is a general problem identification method that uses cognitive mapping as a modeling device for eliciting and recording individual’s views of a problem situation. The merged individual cognitive maps (or a joint map) provide the

framework for group discussions, and a facilitator guides participants towards commitment to a portfolio of actions (Mingers, 2011).
SODA was developed by Colin Eden and colleagues at Bath University as a means of enabling ‘‘a group or individual to construct a graphical representation of a problematic situation, and thus explore options and their ramifications with respect to a complex system of goals or objectives. In addition, the method aims to help groups arrive at a negotiated agreement about how to act to resolve the situation’’ (Mingers, 2000). Although originally focusing on supporting messy complex problems, over the years it has now become strongly associated with strategy making (Ackermann & Eden, 2011).

The method has as its foundation the research of (Kelly, 1955) and relies upon the use of either cognitive or cause maps, to elicit representations of how individuals perceive the problem situation. These maps, can be constructed individually (creating cognitive maps) and subsequently woven into a single representation (cause map) or developed interactively with the group in real time. In addition, maps can be generated and explored either manually or using varying degrees of computer support depending on the group, context and facilitator’s preference. The combined causal map acts as a powerful mechanism for helping portray a comprehensive network of statements and relationships which enable the development of a shared understanding as participants make sense of one another’s perspectives (Weick, 1979). In any mode, but particularly when using the software (Decision Explorer) the maps are able to be edited and augmented enabling the map to shift from being an mixture of divergent points of view to a more convergent representation thus facilitating negotiation as members are able to change their mind without penalty. At any time the map – a directed graph –is amendable to analysis allowing emergent properties to be detected and helping to increase the rationality of the final decision (Eden & Spenders, 1998).
SODA is mainly used in strategy making process as:

- Surface the emergent strategy of the organization in terms of strategic issues, aspirations and taken-for-granted beliefs using cognitive maps and the oval mapping technique. This involves individual interviews and facilitated workshops.
- Undertake intensive group discussions and negotiations to develop agreements for action: JOintly Understanding, Reflecting and NEgotiating strategY (JOURNEY-making) using facilitated workshops, group strategy maps and specially created decision support software (Decision Explorer, Banxia Software).
- Monitor progress of the strategy and gain organizational learning.

2.6.3 Strategic Choice Approach (SCA)

Strategic choice approach (SCA) is a PSM centered on managing uncertainty in strategic situations. Facilitators assist participants to model the interconnectedness of decision areas.

Interactive comparison of alternative decision schemes helps them to bring key uncertainties to the surface. On this basis the group identifies priority areas for partial commitment, and designs explorations and contingency plans.

The strategic choice approach (SCA) was developed by John Friend and colleagues beginning during the 1960s at the Institute for Operational Research which was collaboration between OR Society and Travistock Institute of Human Relations (Friend, 2006). It initially arose out of work with public sector organizations, especially local authorities and town planning departments, and was particularly informed by the social science approach of the Tavistock and the concerns of the professional decision-makers who were clients. This approach has been discussed and used widely in literature (Friend & Jessop, 1977; Friend, 2006).

The approach recognizes differing stakeholders and viewpoints, and significant elements of uncertainty and lack of information. It generally involves related decision problems that are under consideration and consists of four stages:

- The shaping mode: initially decision-makers will consider the various decision areas in terms of their inter-relationships and relative importance or urgency. The aim is to select a subset that will form an appropriate focus or boundary for the project.
- The designing mode: for each decision area, possible options are identified and debated. The options are then examined in pairs to see which are mutually incompatible. It is then possible to consider all the possible combinations of options to arrive at a set of potentially feasible decision schemes, which cover all the decision areas. In both these stages areas of uncertainty will become apparent, especially concerning the decision environment, other related decisions that have not included, and values and political considerations.
- The comparing mode: the feasible decision schemes are now compared by evaluating them in terms of several comparison areas or criteria identified by the participants. These will reflect a range of different values possibly held by different stakeholders, and they may well be qualitative and judgmental. A pair-wise comparison of the decision schemes is under- taken using a comparative advantage grid, which identifies where the advantage lies on each dimension of choice, and the extent of uncertainty about this.
- The choosing mode: choices have to be made and different stakeholders have to reach accommodations. At this time, the uncertainties identified earlier must be addressed and some of the agreements may involve delaying some decisions until exploratory actions have occurred to reduce the uncertainty. The agreed combination of commitments and future explorations to reduce uncertainty are expressed in a commitment package.

As with the other methods, this is a participative methodology usually carried out through facilitated workshops of involved parties. For all three of these methods, it is considered preferable for much of the activity to be carried out by participants in the situation, with the

practitioner acting as a facilitator, as they are the ones who have a detailed understanding and it is they who must eventually commit themselves to taking action.

2.6.4 Strategic Assumption Surfacing and Testing (SAST)

Strategic Assumption Surfacing and Testing (SAST), like other PSM is used primarily in situations where differences of opinion are preventing a group's ability to tackle an ill-structured problem (Mason & Mitroff, 1981). The method seeks to examine a group's preferred strategy for dealing with a problem by identifying, discussing, and understanding the assumptions on which the strategy is based. The five phases of SAST are:

- **Group Formation.** The large group is divided into groups of 6-8 participants (either randomly allocated or purposely assigned) and the focus then turns to team building within the groups.
- **Assumption Surfacing.** Groups are asked to identify the stakeholders that will be affected by the problem at hand; and then asked to generate a list of assumptions relating to those stakeholders that will enable an optimal outcome of the problem.
- **Intra-Group Rating**. Groups are then asked to eliminate irrelevant assumptions and rate the remainder. This is commonly aided by generating an Importance/Certainty matrix that helps the group to rank their assumptions in priority order (Mason & Mitroff, 1981).
- **Inter-Group Debate.** Once groups have ranked their assumptions they rejoin the larger group to present their assumptions and engage in a group debate. A combined assumptions list is produced.
- **Final Synthesis**. Once all participants agree that the list of assumptions is thorough, the group sets about prioritizing a list of issues, assesses their organization's state of knowledge with respect to these issues, and develops a list of activities designed to improve knowledge on the issues.

The information obtained from the final synthesis is then used to develop and implement the proposed strategy.

2.6.5 Robustness Analysis

Robustness analysis (RA) is an approach that focuses on maintaining useful flexibility under uncertainty. In an interactive process, participants and analysts assess both the compatibility of alternative initial commitments with possible future configurations of the system being planned for, and the performance of each configuration in feasible future environments. This enables them to compare the flexibility maintained by alternative initial commitments.
Robustness Analysis (RA) provides an approach to the structuring of problem situations in which uncertainty is high, and where decisions can or must be staged sequentially. The specific focus of

RA is on how the distinction between decisions and plans can be exploited to maintain flexibility under uncertainty (Rosenhead, 1980). RA does this by identifying early decisions which allow a range of options and therefore add degree of flexibility to the decision-making process. RA is an iterative process where analysts and participants assess the compatibility of:

- alternative initial commitments (current and committed states of the system that together specify the impending system) with
- Possible future configurations of the system being planned for; and the performance of each configuration in a feasible future environment.

The result is a list of possible decisions rated in terms of their robustness against a variety of projected futures.

2.6.6 Viable System Model (VSM):

Viable systems model (VSM) is a model of a viable organization based on cybernetic principles. It specifies five notional systems that should exist within an organization in some form—operations, co-ordination, control, intelligence, and policy, together with the appropriate control and communicational relationships. Although it was developed with a prescriptive intent, it can also be used as part of a debate about problems of organizational design and redesign (Harnden, 1990).

The Viable Systems Model (VSM) presents a theory of organizational viability by applying notions from cybernetic theory to organization (Beer, 1985). The underlying assumption of the model is that the central task for any organization is to strive for viability, which Beer defines as being able to maintain a separate existence. In order to achieve this separate existence and therefore viability, Beer asserts that the following five functions must be properly implemented:

- **Collection of Primary Activities**: the primary activities realize the identity of a viable system. In a research organization, for instance, the primary activities would include doing research and providing advice
- **Coordination**: the coordination function ensures that the interdependencies between the primary activities are coordinated.
- **Control**: the control function ensures synergy among the primary activities and monitors whether the goals of these activities are being realized.
- **Intelligence**: the intelligence function initiates adaptation of new organizational goals by ensuring that the activities of the organization remain aligned with environmental developments.
- **Policy**: the policy function links control and intelligence and ensures that the organization defines its identity and long-term strategy.

Applications of the VSM seek to critically examine each of these functions in consultation with key stakeholders in an organization. Both the goals (desired outcomes for the specific variables) and the signals (actual outcomes for the specific variables) are assessed to identify gaps. Gaps can then be closed through adjustment of the goal or through implementing certain interventions to realize the goal. With all gaps closed the five functions can be successfully implemented and viability obtained (Achterbergh & Vriens, 2002).

Chapter 3
Multimethodology

Various approaches, from different viewpoints and paradigms, methodologies and methods, within the fields of Management Science, Operations Research and Systems Analysis, have been discussed in the previous chapter. Each presents different characteristics and some classifications are proposed in relation to their characteristics, aims and actual usability. Galliers and Land (1987) propose "taxonomy of research approaches", in Information System research context, when dealing with society, organizational groups, individuals, technology and methodology. A comparison of PSM and some criteria of classification were proposed in (Rosenhead, 1989) (see section 2.2.4). Flood and Jackson (1991) proposed two dimensions (Level of problem complexity and Level of relationship between participants) to classify the methodologies and a meta-methodology for methodology choice and implementation (see section 2.2.5). Several other classifications are present in literature (see chapter 2) and as research results.

The variety of methods related to hard OR and soft OR is no doubt useful for practice as pointed out by Rosenhead (1989). Classical OR methods such as linear programming are useful in case of clearly defined problem and goal, with limited uncertainties related to data. Soft OR is useful in tackling unstructured problems, involving different stakeholders with varying viewpoints and goals. But practitioners usually tend to restrict themselves to one paradigm or one method (Mingers & Brocklesby, 1997). As Ackoff (1977) said, *"Everyone is not equally competent across a wide range of quantitative and qualitative approaches, and we all tend to have our own favorites with which we feel comfortable".*

Nevertheless the diversity of methods has an important and positive side. Researchers and practitioners have the opportunity to mix methods form different fields in order to address the problem situation.
The main research questions in relation to Multimethodology: where and why its need exist; how multimethodology application can be developed in practices. They will be analyzed and discussed in this chapter and frameworks of the different logics will be discussed.

4.1 Definition and Concept of Multimethodology

Galliers and Land (1987) suggested that there are different approaches available and in order to tackle the complexity, the positive aspects of different approaches can be used to make results more acceptable. Jackson (1990) created a categorization of systems methodologies that would allow for their complementary use in specified problem situations. This approach, that combines

together more than one method or methodology (in whole or part) within a particular intervention (Mingers and Gill, 1997), is called *multimethodology*. The concept of 'multimethodology' has been described by (Rosenhead and Mingers, 2001) as: *"The creative combination of methods in order to suit the particular circumstances in which analytic assistance is being offered".*

"Multimethodology is not the name of a single methodology or even of a specific way of combining methodologies together. Rather it refers to the whole area of utilizing a plurality of methodologies or techniques or techniques within the practice of taking action in problematic situations (Mingers & Gill, 1997)". According to this definition, it is clear that multimethodology is a particular form of 'methodological pluralism' (Mingers & Gill, 1997; Midgley, 1997). In other situations, the mixing of methodologies can become very complex, for example when mixing 'parts' of methodologies from different paradigms in a single intervention (Jackson, 1990) or managing the diversity of methodologies within an intervention (Flood, 1995). This is why multimethodology can be viewed as a specific type of 'methodological pluralism'.

4.1.1 The need for Multimethodology

In the previous chapters, we have argued that real life situations having high complexities and uncertainties are not useful to be addressed by hard methods alone. In support of this argument, Mingers (1995) proposed the following 'weaknesses' of hard systems approach:

- Hard systems are geared primarily towards the technological aspects of design, which causes a concentration on technical solutions to what may be complex social, organizational and communicational problems.
- Hard systems are usually orientated towards computerization of existing processes assuming that these processes are effective, or they assume that the end users know what they want and that eliciting user requirements is straight forward.
- Hard systems pay little attention to the wider business and organizational settings within which the information system must operate.
- Hard systems assume a particular positivist (or objectivist) philosophy towards both information and the organizational context, which many argue, is inappropriate

Hard systems approach is insufficient to tackle the complexity and uncertainties involved in real world problems and, therefore, have to be *substituted or complemented* with other approaches that are specifically designed to tackle such situations. In the previous chapters, we have already

explained the transformation journey from the hard to the soft paradigm and then to the critical one. This transformation made it possible for researchers to realize the need of multimethodology concept as it allows the practitioner to address both the quantitative and qualitative aspect of a problem situation (by mixing methodologies) and that different methods can address different phases of an intervention. The following statement endorsed by various researchers highlights the importance of the concept of multimethodology: *it provides the wherewithal to manage the complete cycle of interventions from the initial diagnosis of the problem to taking action* (Jackson and Keys, 1984; Bennett and Cropper, 1990; Mingers and Brocklesby, 1997).

Mingers in his work stresses the importance of multimethodology based on the fact that some methodologies tend to be more useful in some phases as compared to others and mixing them may yield better results. Some of the arguments in favor of multimethodology are provided below (Mingers, 2000; Mingers, 2001):

- The real-world problem situations are multi-dimensional and highly complex. Different dimensions and paradigms focus their attention on different aspects of problem. That is why multimethodology is necessary in order to combine different viewpoints and dimensions to address the problem situation.
- An intervention is not a single discreet event, but it is a process that typically proceeds through a number of phases, and these phases pose different tasks and problems for the practitioner.
- Multimethodology, an almost recent innovation is being deployed in practice to modern post millennium technology solution requirements.

Mitroff and Linstone (1993) also propagated the need of multimethodology in these words: *"If we have to have precise definitions of complex problems before we can proceed, and if in order to obtain such precise definitions we need to base them on the adoption of a single scientific discipline or profession, then precision and clarity may lead us deeper into deception and not rescue us from it. By selecting a single scientific discipline or profession, we cut off innumerable other pathways that we could have chosen to explore the nature of our problem".*

There are applications of multiple methodologies in literature, in relation to different disciplines and for different aims. For social research, the concept of multimethodology is used when both qualitative and quantitative research are accepted and used as compliments to each other (Neumanm, 2003). The use of multiple methodologies prevents the limitation of research to one method (Abrahamson, 1983). According to Abrahamson, 'the strength of almost every measure

is flawed in some way or other, and therefore research designs and strategies can be offset by counter balancing strengths from one to another'.

As far as management science research is concerned, the application of different methods was present in the past. Even if the different methods perform the same functions, mixing them can often provide a 'triangulation' which can be defined as, *"seeking to validate data and results by combining a range of data sources, methods or analysts"* (Todd, 1979; Greene et al, 1989). Todd (1979) thinks that this triangulation can help to generate new insights into the problem situation and provide validation to the obtained results. His point of view may be partially contradicted by the observation that if we have different methods they are different and created for different aims. Therefore the results of different methods could be different and the validity of all the results may be the same. In the management science context the approach of qualitative and quantitative mixing across the same or different paradigms is now used (Easterby-Smith et al, 2002).

4.1.2Multimethodology in practice

In certain situations, mixing methodologies in order to apply to a specific intervention is theoretically uncomplicated. In other situations, the mixing of methodologies can become very complex, for example when mixing 'parts' of methodologies from different paradigms in a single intervention (Jackson, 1990) or managing the diversity of methodologies within an intervention (Flood, 1995).

Five purposes of applying multiple methodologies are proposed in (Greene et al, 1989):

- 'Triangulation' or seeking convergence of results
- 'Complementarity' or examining overlapping and different facets of a phenomenon.
- 'Initiation' or discovering paradoxes, contradictions, fresh perspectives.
- 'Development' or using the methods sequentially, such that results from the first method inform the use of the second method.
- 'Expansion', or mixed methods adding breadth and scope to the project.

Mingers and Brocklesby (1997) identified four phases for multimethodology interventions in practice:

- **'Appreciation':** Appreciation of the situation as experienced by the involved practitioner and expressed by any actors in the situation. This will involve an initial identification of

the concerns to be addressed, conceptualization and design of the study, and the production of basic data using such methods as observation, interviews, experiments, surveys, or qualitative approaches.

- **'Analysis':** Analysis of the produced information so as to be able to understand and explain the situation as it is. This would involve analytical methods appropriate to the goal(s) of the intervention and the information produced in the first phase. Explanations will be in terms of possible hypothetical mechanisms or structure that, if they existed, would produce the phenomena that have been observed, measured, or experienced.

- **'Assessment':** Assessment of the postulated explanation(s) in terms of other predicted effects, alternative possible explanations, and consideration of ways in which the situation could be other than it is. Interpretations of the results, and inference to other situations.

- **'Action':** Action to bring about changes, if necessary or desired.

The phased approach in designing a multimethodology intervention is also supported by Ormerod (1997), who is of the opinion that the intervention will be easier to understand and manage if broken up in phases. He proposes that the type of multimethodology to be used in an intervention should be negotiated with the end user or sponsor. This author supports this approach as the intervention in this thesis is focused on a particular area of application, namely the financial services industry, specifically customized for this purpose to fulfill the expectations and requirements of the end user or sponsor.

Mingers (2001) suggests an approach to multimethodology, whereby parts of methodologies are linked together, as opposed to combining whole methodologies. This would then require a detailed study of the different methodologies to determine where fruitful links can be created. An important observation is that the new formulated approach should not be seen as a generic multimethodology, but simply one that is suitable for a particular intervention.

The basic idea behind the deployment of a method for the multimethodology is that it will be applied while reflecting the personal skills, experience values and personality of the practitioner. This observation is supported by Ormerod (1997), who is of the opinion that "practitioners review their range of knowledge and skills and develop their methodological competence". Selection of a method based on the task at hand is impossible according to Mingers (2001) as philosophically and practically, practitioners use their meta-knowledge to address problem situations.

4.1.2.1 Surveys on the practice of multimethodology

Munro and Mingers (2002) published a paper regarding the practice of multimethodology based on a survey of practitioners and academics mainly in the UK. Their paper presented important results concerning the types of methods used in multimethodology, the reason of the selection of methods, and the level of success the practitioners attributed towards multimethodology. The results of this survey were also cited in a book by Rosenhead and Mingers (2001). The survey results showed that most common mixing of methods occurred in pair of two (Table 3.1) and in a combination of three methods (triads of methods) (Table 3.2). The results published in the paper are important in the context that it provided a systematic and holistic point of view for the future research regarding multimethodology.

Table 3.1
Pairs of methods (Source: Rosenhead & Mingers 2001)

Method 1	Method 2	Number of reported uses
Discrete Event Simulation	Statistical Analysis	13
Forecasting	Statistical Analysis	9
SWOT	Soft System Methodology	9
Discrete Event Simulation	Soft System Methodology	8
Influence Diagram	Soft System Methodology	8
Strategic Choice	Soft System Methodology	8
Critical System Heuristics	Soft System Methodology	7
Soft System Methodology	Interactive Planning	7
Soft System Methodology	Cognitive Mapping	7
Statistical Analysis	Soft System Methodology	7
Viable System Model	Soft System Methodology	7
Mathematical Programing	Statistical Analysis	7
Mathematical Programing	Discrete Event Simulation	7
Structured Analysis & design	Soft System Methodology	6
Mathematical Programing	Heuristics/ Combinatorial Optimization	5
Decision Analysis	Strategic Choice	5
Decision Analysis	Cognitive Mapping	5
Statistical Analysis	Cognitive Mapping	5
Influence Diagram	Viable System Model	5
Influence Diagram	Soft System Methodology	5
Strategic Choice	Cognitive Mapping	5
Interactive Planning	Critical System Heuristics	5
Strategic Choice	Interactive Planning	5

Table 3.2
Triads of methods (Source: Rosenhead & Mingers, 2001)

Method 1	Method 2	Method 3
Strategic Choice	Soft System Methodology	Interactive Planning
Mathematical Programing	Discrete Event Simulation	Statistics
Mathematical Programing	Discrete Event Simulation	Heuristics/ Combinatorial Optimization
Statistical Analysis	Influence Diagram	Cognitive Mapping
Statistical Analysis	SWOT	Soft System Methodology
Statistical Analysis	Soft System Methodology	Cognitive Mapping
Statistical Analysis	Project networks	Forecasting
Statistical Analysis	Forecasting	Inventory
Soft System Methodology	Viable System Model	Strategic Choice
Soft System Methodology	Viable System Model	TSI
Soft System Methodology	Viable System Model	CSH
Soft System Methodology	Interactive Planning	CSH
Soft System Methodology	Scenario Planning	CSH
Cognitive Mapping	Delphi Method	Scenario Planning
Cognitive Mapping	Delphi Method	Scenario Planning
Cognitive Mapping	Delphi Method	System Dynamics
Cognitive Mapping	Decision Analysis	Strategic Choice
Hypergame	Influence Diagram	System Dynamics

Reinforcing the observations made in the tables above, Rosenhead & Mingers (2001) make this interesting remark, "the soft systems methodology is used extensively as a methodology that can be combined with many others." Moreover, Munro & Mingers (2002) also state that, "SSM is distinctive in that it appears to be the predominant methodology as part of a multimethodology, in combination with other techniques." Another interesting observation that can be made from these tables is that there are relatively fewer combinations across different paradigms (i.e. hard and soft). Most of the combinations are of either hard methods or soft methods. The instances of combination of hard and soft methods involve the combination of simulation and SSM; statistical analysis with SSM and structured analysis & design with SSM. As far as the choice of a particular method is concerned, Munro and Mingers argue that "choice depends to a significant extent on the particular experiences and competencies of the practitioners involved." The "tacit knowledge" held by the practitioners makes it hard to articulate why a specific methodology was chosen as it depends on the past experiences and skills.

Building upon the lessons learnt by Munro & Mingers and keeping in view that extensive work had been carried out following the survey; Howick and Ackermann (2011) published a review paper with the aim of knowing that are there any methods more suitable for a specific problem situation or objectives. The methods used in the paper are provided in table 3.

Table 3.3
Dominant Methods Mixed (Source: Howick and Ackermann, 2011)

Methods Mixed
Cause mapping, system dynamics (SD)
SODA, Multicriteria decision analysis (MCDA)
Qualitative systems models, data analysis, discrete-event simulation (DES)
Delphi & grass root forecasting
Soft systems methodology (SSM), data mining
Strategic choice approach (SCA), Strategic options development analysis (SODA)
Influence diagram, decision tree, MAUT
Journey making, data envelopment analysis
DES, data mining
SSM, SD
DES, group support system
Scenario building, rich pictures
SCA, SSM
SCA, SSM,SODA
SD, Scenario mapping
SSM, DES
Cognitive mapping, SCA, SSM
Interactive planning, SCA, SSM, viable systems model
MCDA, SSM
DES, cognitive mapping
SD, conjoint analysis

As in the case of Munro and Mingers survey, also here some methods are more dominant. Howick and Ackermann found out that SSM is the most dominantly used method. The reason they put forward is that facilitator knowledge and past experiences and also clients understanding of a method through "experience or word of mouth". Moreover, qualitative methods are used predominantly more than quantitative methods when mixing as depicted in Table 4. The observations made by Howick and Ackermann are interesting as they also focus on the types of mixinig of methods. According to them, 3 types of mixing between quantitative and qualitative methods occurs: Sequential (Linear-one after the other), parallel (Comparison purposes) and interactive (Continuous Interaction throughout process). In the papers analyzed, the focus was not only on the mixing between quantitative and qualitative methods but also the inter-mixing of the two types of methods. The results have been presented in the graphs in Figure 3.1. As can be seen, the most common mixing is between quantitative and qualitative and is generally interactive. When two or more qualitative methods are mixed, however, the mixing is sequential. Mixing between two or quantitative methods is the least common one and is dominantly interactive.

Table 3.4
Most common methods used in the interventions (Source: Howick and Ackermann, 2011)

Technique	No. of papers cited in the survey
SSM	12
Discrete Event Simulation	8
SCA	8
System Dynamics	7
SODA	7

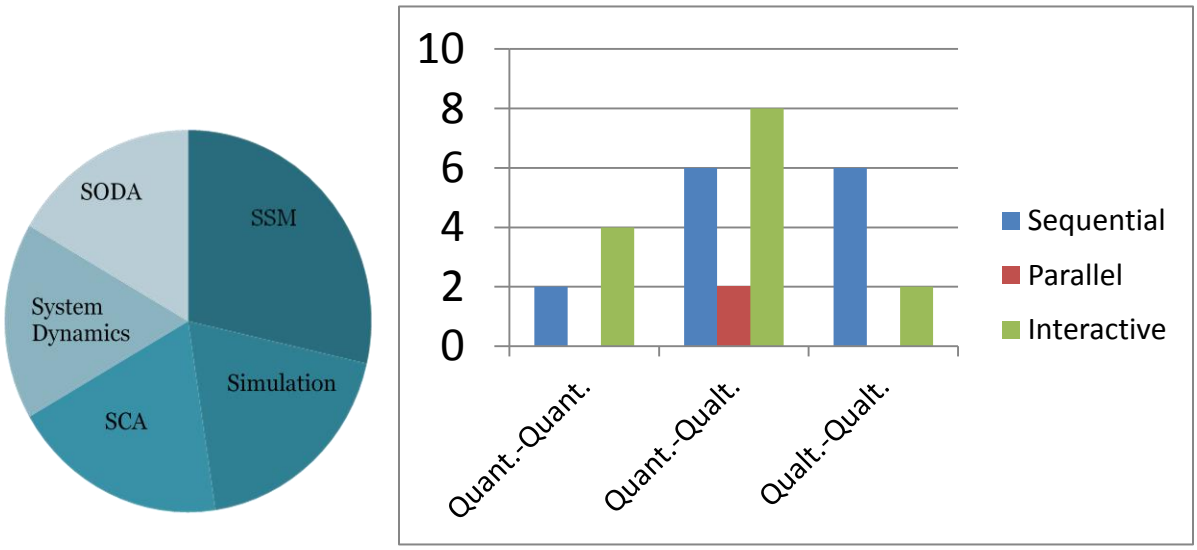


Figure 3.1: Graphs of the common methods and the types of mixing

3.2 Combining PSM and Multi Criteria Decision Analysis (MCDA)

3.2.1 Introduction to MCDA

Multi Criteria Decision Analysis (MCDA) is a part of OR that explicitly involves multiple criteria in a decision making process. Belton & Stewart (2002) define MCDA as, "an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter". As can be seen

clearly in the definition, there are three important points or dimensions regarding MCDA; (1) a formal approach, (2) presence of multiple criteria and (3) decision making process involves individuals or group or individuals.

Basically, MCDA inhibits some characteristics that make it interesting and practically useful. Belton and Stewart (2002) represented some of these properties as: (1) ‘‘it seeks to take explicit account of multiple, conflicting criteria’’, (2) it helps to structure the management problem, (3) it provides a model that can serve as a focus for discussion, and (4) it offers a process that leads to rational, justifiable, and explainable decisions. Moreover, MCDA also has some desirable features that make it an appropriate tool for analyzing complex problems. First, it can deal with mixed sets of data, quantitative and qualitative, including expert opinions. This uncertainty related to data exists as normally data is incomplete or misunderstood. Hence, the capability to accommodate these gaps in information and knowledge through qualitative data, expert opinions, or experiential knowledge is a distinct advantage. Secondly, MCDA accommodates a collaborative approach for the decision making environment. This collaborative environment accommodates the involvement and participation of multiple experts and stakeholders (Mendoza and Prabhu, 2003; Mendoza and Martins, 2006).

Because the aforementioned dimensions and importance of MCDA, it has been widely used in decision making processes ever since its inception in the late 1960’s and 1970’s (Keeney and Raiffa, 1976). But it was after the inception of “soft OR” methods that the MCDA practitioners began to understand the importance of structuring in MCDA models using these approaches, particularly cognitive mapping (Brownlow & Watson, 1987; Buede, 1986). The need for structuring in ill-structured problem situations is described in following words by Keeney:

> *“Invariably, existing methodologies are applied to decision problems once they are structured . . . such methodologies are not very helpful for the ill-defined decision problems where one is in a major quandary about what to do or even what can possibly be done….. What is missing in most decision making methodologies is a philosophical approach and methodological help to understand and articulate values and to use them to identify decision opportunities and to create alternatives.”* (Keeney, 1992)

In the book by Belton & Stewart (2002), they have not only explained the importance of structuring in MCDA interventions but also have included problem structuring as a necessary part of MCDA process.

The starting point of a MCDA process is a well-defined problem situation which states the following elements:

- The set of alternatives or decision space from which a choice (decision) has to be made
- The set of criteria against which the alternatives are to be evaluated
- The model, or method, to be used to effect that evaluation

As has already been explained in this chapter and the previous chapters, the situation as far as the problem definition is concerned, is not simple but is highly complex and ill-structured. Thus, the role for problem structuring for MCDA may be to provide a rich representation of a problematic situation in order to enable an effective Multicriteria analysis. This can be achieved by ensuring that the Multicriteria problem is properly framed and structured and for this purpose, the following questions have to be answered:

Who are the relevant stakeholders? In any decision, whether personal or organizational, there are likely to be multiple stakeholders – clients, decision makers, those affected by a decision, those who have to implement it. Who are they? Should they be involved in the process? What are their views, should they be taken into account and if so, how?

Are there key uncertainties or constraints and how should these be managed? There are inevitably internal or external uncertainties of some form and it is important to assess whether these should be explicitly incorporated in some way in the multicriteria model, explored through sensitivity or scenario analysis, or are not judged to be a significant concern.

What is the appropriate framework? Different views may emerge for a number of reasons, for example: different stakeholder perspectives, or worldviews; the output of a process of creative thinking; or the consequence of critical reflection on an issue. Differently framed decisions can surface very different alternatives and criteria, potentially leading to different outcomes.

The approaches of PSM (as described in the last chapter), offer a representative way to answer specifically the questions mentioned above. PSM support fuller consideration of such issues with the aim of achieving a unified view of the problem situation.

3.2.2 The approaches for structuring in MCDA

Structuring in MCDA interventions has usually followed two schools of thought. One is to manage the structuring within the existing framework of MCDA model. Keeney's value focused thinking (VFT) is an example of this approach (Keeney, 1992). Once a decision problem or opportunity has been recognized, VFT emphasizes the stages of surfacing and understanding the decision makers' values, and associated objectives and then using these as the basis for creative generation of alternatives prior to evaluation of selected alternatives and selection of preferred ones. Understanding the decision frame, defined by the decision context and associated fundamental objectives, is key to VFT and the set of alternatives for consideration should only be established, with an emphasis on creative design of good candidates, once the frame is clear. Keeney stresses that these three components (frame, alternatives, and objectives) should be specified coherently. Keeney contrasted value focused thinking with alternative focused thinking, starting from a specified set of alternatives and using these as the stimulus to identify values.

Another framework proposed by Corner et al (2001) is called "dynamic decision problem structuring". This approach was useful because of the inter-related nature of the components of a problem situation and there was a need to explore these interactions and employ them in the process of learning about the issue. This approach makes explicit and actively encourages a continuing process of iteration between value focused thinking and alternative focused thinking as can be seen in figure 2. Consideration of values prompts creative thinking about possible alternatives, which in turn surface new values, and so on. The iterative process encourages decision makers to reflect on and learn about their values and the problem context.

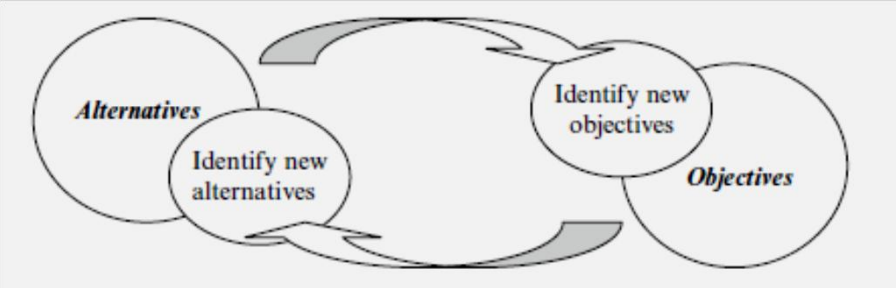


Figure 3.2: An illustration of the process of "dynamic decision problem structuring" (Corner et al, 2001)

A second stream of development in problem structuring for MCDA has been research directed towards integration of one of the problem structuring methods. The majority of published applications have combined cognitive / causal mapping (Eden and Ackermann, 1998; 2001). Neves et al (2004) use Checkland's Soft Systems Methodology (SSM) to structure thinking and analysis of new initiatives to improve energy efficiency. Interestingly, the authors define the process of analysis of options, based on multiple perspectives, as a part of the SSM model. Daellenbach (1997) and Daellenbach and Nilakant (1999) also discuss the potential for SSM to support problem structuring for MCDA. In the next section, we will describe the potential of integration between MCDA and PSM in detail.

3.2.3 The Potential of integration between PSM and MCDA

3.2.3.1 The point of view of Belton and Stewart (2002)

PSM explanation and their characteristics have been well-explained in the chapter 2. The key features of the five PSM approaches and the potential for integration with MCDA are summarized in Table 5. According to the authors of this table, The first three of these approaches – SODA, SSM and SCA – are the most generally applicable (authors call these methods as general PSM), in the sense that they can be used to surface ideas and structure thinking with respect to any broadly defined issue, and, as a consequence, the most widely known and applied. Robustness Analysis has a particular focus on consideration of uncertainty about the future and

Drama Theory on the tensions underlying the potential for cooperation or conflict between multiple parties.

Table 3.5
Problem structuring methods and the link to MCDA (Source: Belton & Stewart, 2002)

Method	Key Feature	Potential link to MCDA
SODA	Beginning with a process of idea generation, seeks to capture and structure the complexity of an issue reflected by multiple perspectives.	Can be used flexibly with MCDA, as a precursor or in an integrated manner. Incorporates simple, holistic preference
SSM	Uses rich pictures, CATWOE, root definitions and conceptual models to explore the issue from a number of different perspectives	Can be used flexibly with MCDA, as a precursor or in an integrated manner.
SCA	Four modes – Shaping, Designing, Comparing, Choosing. Focuses on key uncertainties (about related areas, environment and values) and analysis of interconnected decision options	Parallels MCDA – shaping and designing highlight key choices and comparing evaluates these using a simple form of multicriteria evaluation
Robustness Analysis	Focuses on identifying options which perform well in all possible futures	Complementary to MCDA – focus on different aspects of an issue
Drama Theory	Appropriate in multi-party contexts, where the outcome is dependent on the inter-dependent actions of the parties – seeks to identify stable options	Drama theory requires possible futures to be ranked according to preference, which is done holistically

In exploring how PSMs and MCDA might be combined it may be helpful to distinguish between process and modeling. Although all PSMs stress the importance of a participative process, many considerations are general in nature and applicable to many forms of process consultancy, including a participative approach to MCDA (Dias and Mousseau, 2006). SODA is the only PSM which pays explicit attention to process, distinguishing different modes of working. In the first of these steps or modes, individual cognitive maps are developed in 1 to 1 interviews with participants; these maps are then merged to create a group map which provides the starting point for a facilitated workshop. In the next step, participants are jointly involved in creating a shared model in a facilitated workshop, either using a manual Oval Mapping process, or a direct entry multi-user system. An intervention using MCDA, in isolation or in combination with mapping or another PSM, might adopt any of these three processes (Belton and Stewart, 2002). The question then becomes one of how the modeling methods which define the different approaches to problem structuring and MCDA can be effectively combined. Figure 3.3 provides three possible ways to do so.

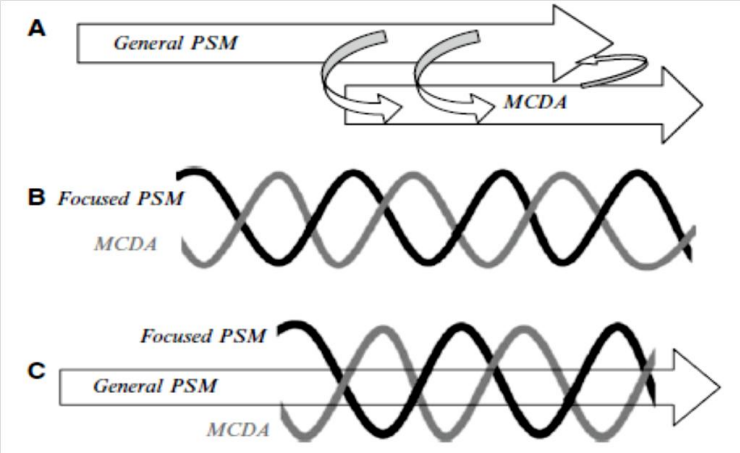


Figure 3.3: Combining PSM a multicriterai modeling (Source: Belton & Stewart, 2002)

In figure 3.3A, the more natural way of combining PSM and MCDA is represented with the problem structuring phase supported by one of the more general PSM and providing a rich description of the problem from which an appropriate multicriteria model may be derived. Figure 3.3B illustrates a way of working which is more likely if using MCDA with one of the more focused PSM but this interaction can be further enhanced if started and supported by a general PSM as represented in Figure 3.3C. We will provide examples in order to make these ideas more clear.

3.2.3.2 The point of view of Franco and Montibeller (2009)

Franco and Montibeller in their paper suggest a framework for conducting MCDA interventions, in which the role of problem structuring is made explicit. In Phase 1, the analyst structures the problem situation, helping the client to create a problem definition, and designs a decision process with the right level of participation. Once this phase is finished, the analyst then can start Phase 2, the structuring of an MCDA model, which consists of structuring a value tree, developing attributes and indentifying decision alternatives. With this second phase completed, the analyst can finally conduct Phase 3, the evaluation of decision alternatives. The natural flow of phases is indicated with black arrow in the Figure 4, but notice that the process is recursive (grey arrows): back from Phase 2 to Phase 1, if the structuring of the MCDA model changes the definition of the problem or the scope of stakeholders' participation; back from Phase 3 to Phase 2, if the assessment of alternatives changes the structure of the MCDA model; and back from Phase 3 to Phase 1, if the assessment of alternatives changes either the definition of the problem or the participation required.

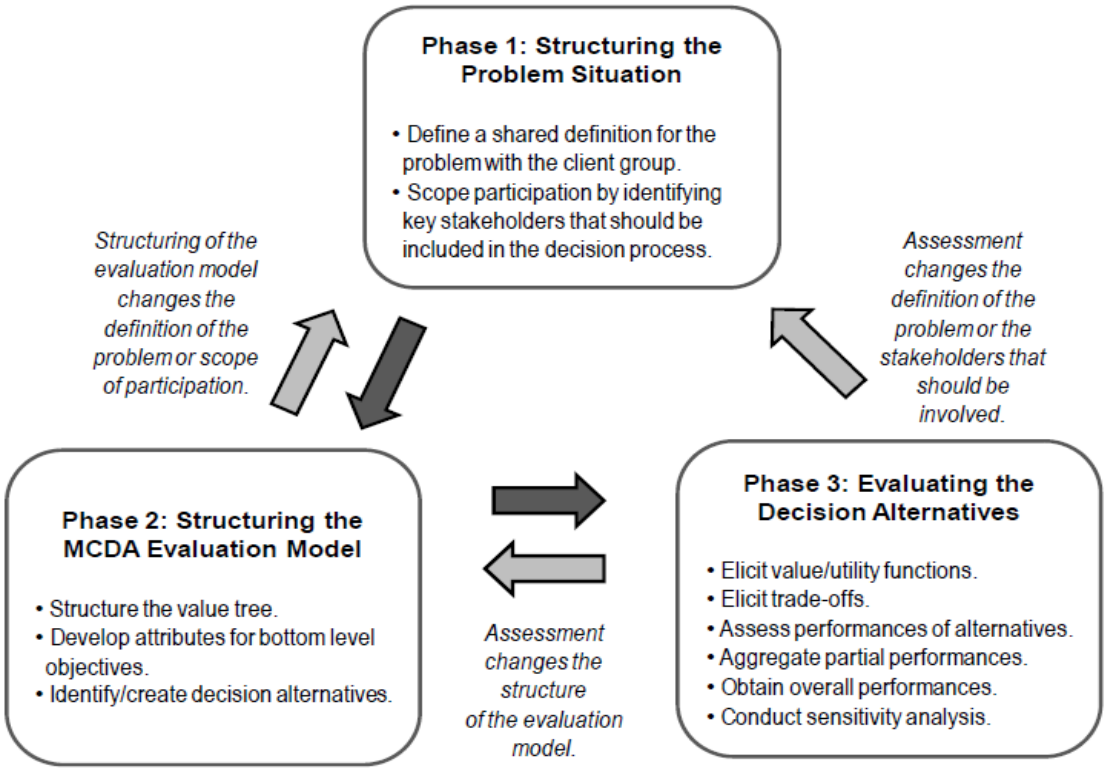


Figure 3.4: Framework proposed by Franco and Montibeller (2009)

While the authors provide a general framework for structuring phase in MCDA interventions, they also provide list of useful tools that can be used within each of the structuring phases of an MCDA intervention (Franco and Montibeller, 2009). Problem structuring methods (PSM) in the view of the authors are more appropriate for use in the phase 1 of the framework as depicted in Table 6, for the purpose of defining the problem.

Table 3.6
Tasks and tools for problem structuring phase (Franco and Montibeller, 2009)

Phase 1: Problem Structuring		
Activity	**Task**	**Supporting Tools**
Defining the problem	Capture the different understandings about the multi-criteria problem and facilitate a definition of the problem that is shared by the client (or client group).	• Cognitive mapping • SSM • SCA • Group Model building • Decision Framing
Scoping Participation	Determine the type and level of participation of different stakeholders required for the intervention.	• Stakeholder Influence Diagram • Stakeholder issue-interrelation diagram

3.3.3 Case Studies: Structuring for MCDA Interventions

3.3.3.1 Combination of SSM and MCDA

SSM can be integrated into the problem structuring phase of a MCDA model as it helps to define clearly the decision problem context and the main stakeholders involved, as well as to unveil the relevant objectives for each stakeholder. With SSM it is possible to look at the whole context of problem situation is taken, defining a system for providing decision support on, and to devise all possible implications of this decision.

Meeting Customer Needs: From SSM to Multi-attribute Value Analysis via CAUSE *(Belton & Stewart, 2002)*

The client in this case study was the Managing Director (MD) of King Communications and Security Ltd., a Scotland-based SME providing integrated security and telecommunications solutions to business. The MD has been in post for less than a year and is seeking to improve customer service at a time of substantial business growth.

The four elements of the SSM learning cycle are: a process of finding out about a problematical situation; exploration of the situation through the building of a number of purposeful activity models relevant to the situation, each corresponding to a clearly defined worldview; use of the models to prompt questions and structure discussion about the real situation with a view to identifying changes that are systemically desirable and culturally feasible; and action to improve the situation.

Rich pictures are probably the most widely known device of SSM; their purpose is visually to represent the main features of a problem situation – the structures, processes, stakeholders, relationships, culture, conflicts, issues, etc. The rich picture ensured that the client and consultants had a shared understanding of the company's organization and focus. After that a CATWOE analysis was performed.

Customers Those organizations that employ KCS to deliver solutions and maintain systems: KCS suppliers

Actors All staff of KCS

Transformation Customer demand for security/telecoms systems? Installed systems which satisfy customer demand

Worldview That KCS is a viable business model that will generate profits for its owners

Owners King family, including the Managing Director

Environment Regulatory bodies, competitors

Finally, the consultants considered the performance measures – the 3 E's – efficacy, efficiency and effectiveness, against which the corresponding activity system would be evaluated.

Efficacy Does the transformation produce the intended outcome – i.e. are systems actually being installed?

Efficiency Is the transformation achieved with minimum use of resources – e.g. are components procured as cheaply as possible, are systems designed, installed and maintained using the appropriate number and level of staff, etc.

Effectiveness Does the transformation help to achieve higher level aims – e.g. are customers satisfied with the service received and systems installed? Is new demand created? Are profits generated?

From these initial considerations it emerged that an issue of particular concern to the MD was the company's ability to meet customer demand in a timely manner, given recently generated growth in demand, shortage of skilled staff and a change in the organizational culture. The initial analysis was done using multi-attribute value analysis, and ELECTRE III was used to validate some aspects of this.

Using SSM to Rethink the Analysis of Energy Efficiency Initiatives (Neves et al, 2004)

This work published in Journal of Operations Research Society reflects an attempt to rethink the process of analysis of energy efficiency initiatives using soft systems methodology (SSM) as a problem structuring tool. The aim of the work is to provide public and private initiative promoters or evaluators with a structured support for a more informed decision regarding the implementation of energy efficiency measures. The SSM approach contributed with the identification of all market players and their relation.

As in the previous case study, SSM was used in the problem definition phase in order to gain insights into problematic situations, and in this case there was a need to gain insight into the problematic concept of the interest of energy efficiency initiatives. The major outcomes of the first stages of SSM were the identification of all the agents in the market, promoting or affected by energy efficiency initiatives, their role in the process and the relations of power. A rich picture was generated and six agents with a potential interest in a system to identify energy efficiency initiatives were identified. After that a CATWOE analysis was performed

Customer: The initiative promoter, the external sponsor if any, the beneficiaries (the consumers who benefit with the initiative, the society as it concerns to environmental and other benefits, the manufacturers and sellers of promoted equipments, etc) and victims (energy companies that reduce sales, manufacturers of the replaced equipments).

Actors: The Decision Maker (DM) who is the promoter of the initiative, or someone who has the responsibility of evaluating it, due to some contract. One of the six entities referred to above: energy agency, energy market regulator, the government, energy companies, energy service companies, equipment manufacturers.

Transformation: Initiative with unknown interest → Interest known.

'Weltanschauung': An initiative is implemented only if its advantages overwhelm its disadvantages to the promoter, including the ones resulting from the reactions of other affected entities.

Owner: The DM, or someone at a degree above in the hierarchy (the government as the power above the agency or the regulator).

Environment: Capability of obtaining relevant data; estimation of initiative success (potential adherence of end users); budget; international agreements and directives.

The 'comparison' of all the advantages and disadvantages to the DM is the objective of this system and it emphasizes the need for a multicriteria decision aid tool.

The monitoring and control activities that are generally included in any SSM model imply the definition of criteria for assessing:

Efficacy Does the system identify correctly a valid energy efficiency initiative?

Efficiency Does the system work with the minimum resources?

Effectiveness Do initiatives well classified by the system actually get implemented?

In the framework of the model proposed by the authors, the last activity is the application of a multicriteria method that opens the possibility of dynamically incorporating the preferences of the DM into the decision support process. In theory, these preferences might be considered during the definition of the cost-benefit or cost-effectiveness formulae as well as during the definition of the conversion formulae for impacts not naturally expressed in currency terms. However, this would be far from easy. What happens usually in current practice is the adoption of existent formulae, therefore ignoring the actual preferences of the DMs. The use of a multicriteria method such as the ELECTRE TRI method which allows for the use of qualitative (ordinal) scales and the definition of weights in a scale-independent manner seems to be a more adequate methodological solution. Moreover, this is generally a classification problem, in which there is the need to classify one or several initiatives into predefined categories of interest (e.g. 'not interesting', 'somewhat interesting', 'very interesting'), the ELECTRE TRI method being especially adequate for addressing this specific multicriteria problem. . ELECTRE TRI requires the setting of weights for the different criteria, and thresholds of indifference, strict preference

and veto for each criterion. It is also necessary to define reference initiatives to be used as boundaries of the ordered categories into which the alternatives will be classified.

3.3.3.2 Combination of cognitive mapping and MCDA

In traditional MCDA setting, two individuals, the decision maker (DM) and the analyst interact with respect to a problem situation. This interaction is intended to help a decision-maker to structure his ideas for handling the problem that he faces. An informal dialogue between the decision maker and the analyst may be sufficient in the case of a single decision maker. In the case of multiple decision-makers or group of stakeholders, this task becomes much more difficult. Eden and Ackermann's cognitive mapping approach presented a formal tool for interacting with a group of stakeholders. The general idea of cognitive mapping is to graphically represent the ideas of a group of actors through a network of concepts and possible causal links. A cognitive map is co-constructed by the participants and the facilitator in a format that is viewable by all participants in the focus group. These groups aim to promote open discussion among participants and stimulate their imagination to make them produce the most ideas in the shortest possible time (brain-storming). The facilitator is the person responsible to conduct and supervise the discussion in a group of individuals.

As pointed out by the two points of views explained in the previous section, cognitive mapping is generally used in the initial phase of a MCDA process to capture the different understandings about the multi-criteria problem and facilitate a definition of the problem that is shared by the client (or client group). As with the SSM, we will consider case studies that help us to know the process of integration of MCDA with cognitive mapping.

Adding Value to Bank Branch Performance Evaluation Using Cognitive Maps and MCDA: A Case Study (Ferreira et al, 2009)

In this paper, the authors aim to show how cognitive mapping and the MACBETH approach can be used to support the evaluation of bank branches through the development of multidimensional performance evaluation systems, and to deal explicitly with the trade-offs between the different dimensions of performance and interests of different stakeholders. The authors chose to use cognitive mapping because they are seen as important tools that aim at helping the facilitator (i.e. researcher, scientist or consultant) in structuring complex problems. They may assume different visual and interactive forms that help individuals to materialize their experiences, thoughts and ideas while discussion and knowledge are promoted. Thus, their use seems to be useful in a bank branch performance evaluation context, not only because they might reduce the omission rate of important criteria, but also because they might promote a deeper understanding of the causal relations between those evaluation criteria.

The case study presented was conducted during a two-year period and it followed the main steps of a 'typical' MCDA – Multiple Criteria Decision Analysis – process. The design of the

performance measurement system was, therefore, organized in three main phases: the first phase, called the structuring phase, was concerned with analyzing the existing performance measurement practices and with applying cognitive maps as a way to identify the key performance areas and the key performance indicators to assess bank branches; the second phase is the evaluation phase, which aimed at applying the MACBETH technique to make explicit the relative importance of each performance area and indicator; the third phase, called the recommendations phase, explored the use of cognitive maps and the MACBETH technique as means of adding value to the existing practices regarding bank branch performance evaluation. The study involved several individual interviews with six bank directors from five of the largest banks operating in Portugal, extensive analysis of relevant information and a series of group meetings, with a two-fold purpose. Firstly, to develop a "new" performance measurement system integrating the use of cognitive maps and the MACBETH approach. Secondly, to explore whether the "new" system could overcome some of the shortfalls of the existing measurement practices, namely, testing whether the process adopted simplified the identification process of the evaluation criteria and introduced transparency in the trade-offs between procedures of those criteria.

The structuring phase involved the identification of actors which were in a group of six members, most of whom were banking experts with coordination responsibilities (e.g. commercial directors and coordination directors). This was, however, a panel of convenience, which resulted from the contacts made by the facilitator and from the availability of the decision makers. The development of individual cognitive maps was, however, the first formal step of the structuring process and took over twelve weeks to be concluded. Several meetings with an average duration of three hours took place and different actors were involved, namely: facilitator, decision makers, psychologist (responsible for providing support in the clarification of some concepts and for facilitating the application of the techniques) and a communication assistant (responsible for the graphic and photographic recording of the sessions). For convenience reasons, and motivated by limitations to the decision makers' availability, it was considered appropriate to start the structuring process following the SODA I approach – Strategic Options Development and Analysis. After the introduction of concepts related to cognitive mapping, individual members were interviewed and cognitive maps generated. After obtaining the individual cognitive maps, the holding of a group session becomes necessary to allow the definition of a collective map, a part of which is shown in Figure 3.5.

In order to move from the individual maps to a collective map, the facilitator, based on the analysis of the individual maps, decided to propose a preliminary version of a group map to the decision makers. This preliminary version aggregated the various concepts given in each of the individual maps and was presented to the group. Through negotiation, the group reached a compromise solution for the problem. During the group working session several aspects were discussed with and among decision makers, and not always a convergence of points of views was

absolutely achieved. However, once a compromise agreement was reached a collective (or strategic) map was defined.

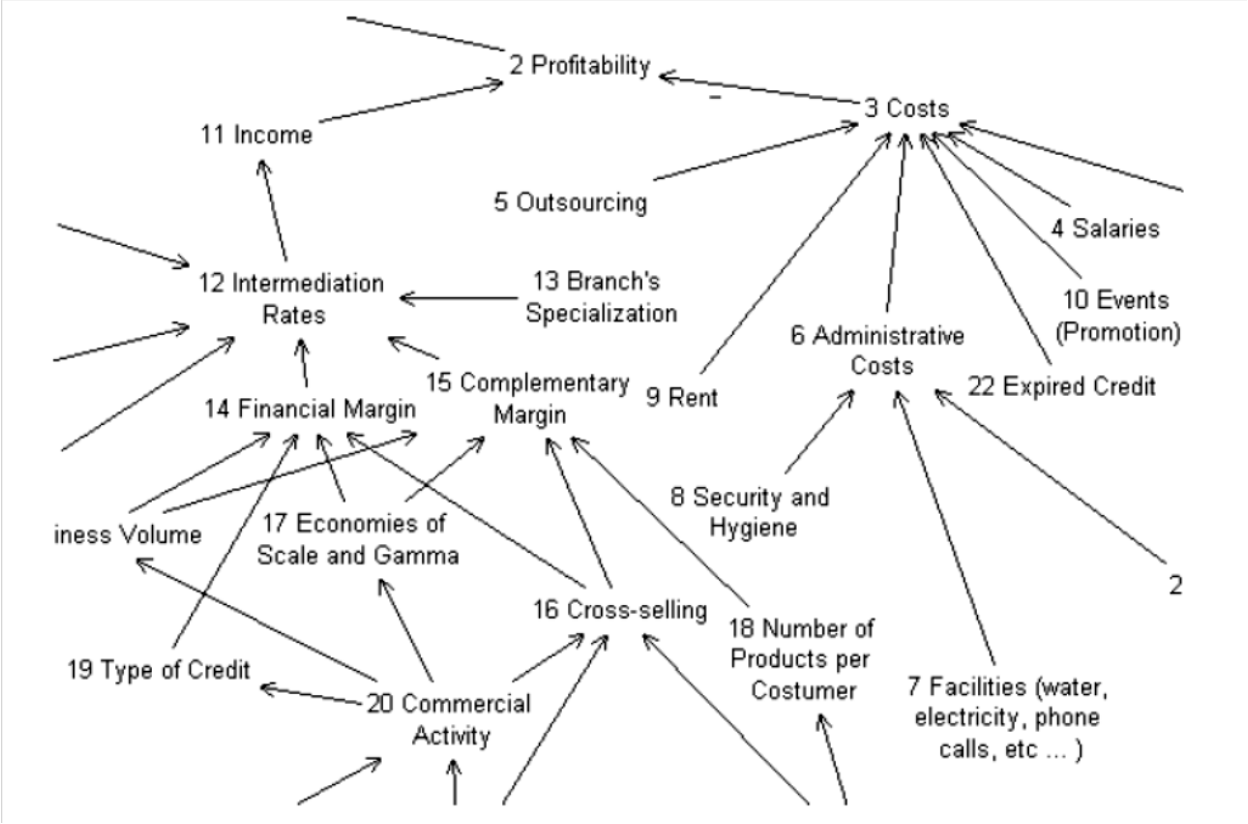


Figure 3.5: Part of a cognitive map (Ferreira et al, 2009)

Based on the collective strategic map, on the increased understanding that emerged from its development, and following methodological processes present in literature, a set of key concepts and performance measures were derived and structured (using the M-MACBETH software) in a performance measures tree. The impact of all the fundamental point of views (FPVs) was carried by using pair-wise comparisons with the help of the actors involved. Secondly, decision makers were asked to project their semantic judgments in relation to the difference of attractiveness between those FPVs. With the projection of those semantic judgments, a MACBETH scale with the trade-offs values was proposed for discussion. Once the trade-offs between the FPVs of the model were obtained, the relative and the overall evaluation of some bank branches became possible. In fact, this enabled the decision makers to assess branch performance and, therefore, to start testing the model and the processes used for its design.

The integrated use of cognitive maps and of the MACBETH approach provides an important tool for discussion and a shared language between the different individuals and groups of decision makers, which facilitates communication and learning. Throughout the modeling process, the participants have the opportunity to share and make explicit mental models they have as well as the priorities and values that influence their decision making.

Integrating Cognitive Mapping Analysis into Multi-Criteria Decision Aiding: Real-world case based on hydrogen technology assessment (Kpoumié et al, 2012)

This study was carried out in France within the context of the AIDHY (Decision support for the identification and support to societal changes brought about by new technologies of Hydrogen. A multidisciplinary project initiated by the French National Research Agency (ANR)) project aiming at (1) Understanding the factors of the social acceptability of hydrogen technologies as an energy carrier, and (2) Providing tools to integrate these factors in development scenarios of these technologies. The introduction of these new technologies in the circuit of mass consumption could meet the opposition or even rejection by the general public. Thus, in such condition of multiple alternatives with different consequences, decisions must be taken in order to establish which technologies or group of technologies should be promoted with respect to social acceptability. This constitutes an assessment problem, an issue that arises in energy planning.

This particular assessment problem is characterized by a high level complexity, regarding both the multiple stakeholders and the social dimensions to be considered. The complexity of the problem suggests the need to adopt an integrated methodology to assist the hydrogen social acceptability process, providing a better understanding of it without leaving important features unattended. For this purpose, a problem structuring approach was adopted. The authors were interested in understanding how different types of stakeholders could react with respect to different scenarios of H2 technologies deployment; three classes of stakeholders: political decision makers, hydrogen industry actors, and the general public (citizens) were identified. However, in the paper only the point of view of citizens has been considered. Initially, cognitive maps relating to groups of individuals who are representative of different sensitivities of the public in relation to energy issues were co-constructed. Then the authors converted these cognitive maps to a value tree of the objectives of the public.

At an early stage of the decision aiding process, authors wanted to share the same understanding of the problem, given the multidisciplinary nature of the project. To this end, through several rounds of discussions with participants including hydrogen experts, in addition to a literature review, we constructed a graphic encompassing its key points. This first study structured the knowledge about hydrogen, and was then submitted to the validation of the expert group in order to focus the work on a shared vision of the problem of hydrogen. This framework is a result of problem structuring, combining group interactions with feedback from other pilot projects in the same field. At this stage of the process, only technical considerations were taken into account. The integration of the social acceptability in the process really began with the construction of the cognitive maps.

Three focus groups were conducted by the second author in order to gather information on the perception of hydrogen by different interest groups. The first author participated as an observer in order to ensure that the need to bring out useful information for an implementation in a valuation model was taken into account within the discussions. Ahead of focus groups, the authors identified specific needs for a multi-criteria analysis perspective such as (i) setting goals and establishing priorities and trade-offs between the competitive ones, and (ii) setting criteria and alternatives. In the implementation of the focus groups, three citizen panels representing the general public were selected on the basis of their affinity with the problem of energy: frequent users of public transport; frequent users of personal car; and users of green technologies of power generation.

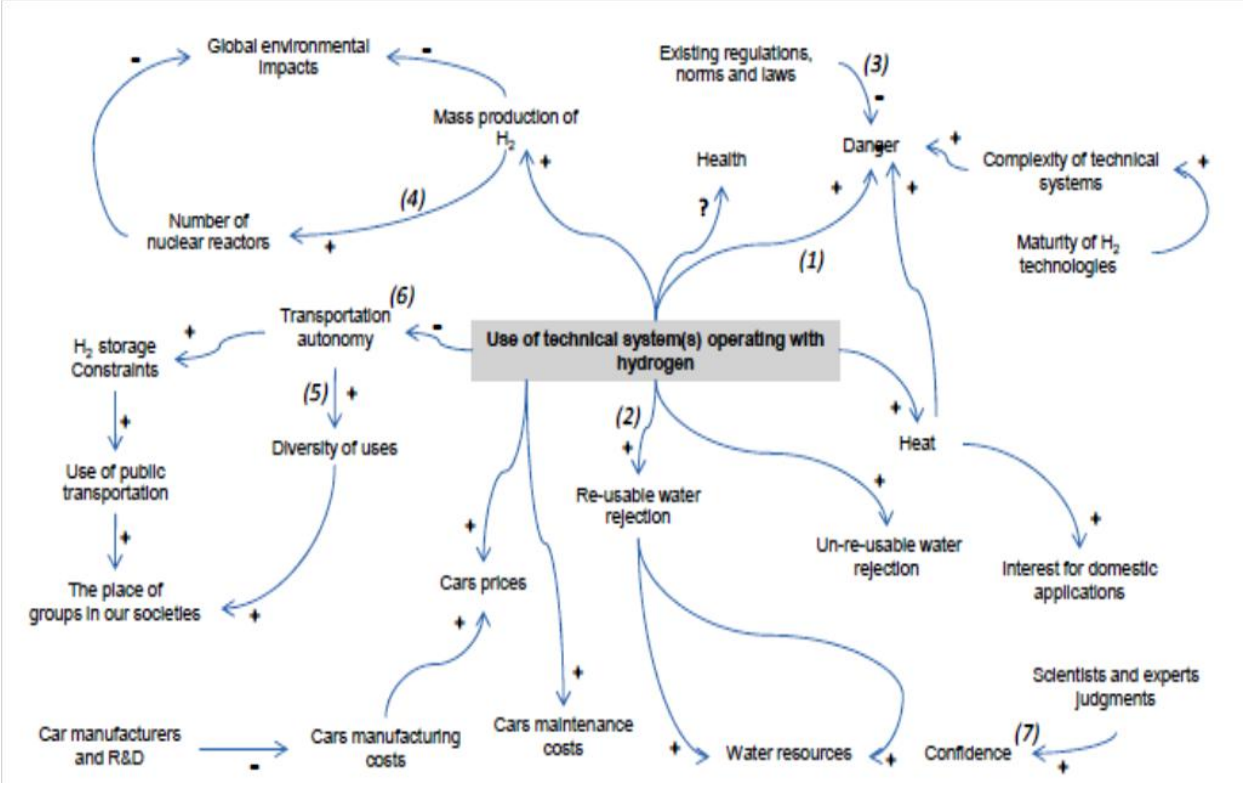


Figure 3.6: Collective cognitive map of frequent users of public transport (Kpoumié et. al, 2012)

The elements identified by generating the cognitive maps were represented in the form of a value tree of objectives. The level selected to be used as evaluation criteria in a decision aiding process needs to be sufficiently detailed in order to allow quantification and measurement, but not that detailed to confuse analysis by drowning decision makers in a plethora of information, deviating them from the main goal of the process. The process of shaping the value tree into an operable form is an important aspect in developing a multi-criteria based decision-aiding process, where an appropriate balance between being too general and too detailed needs to be found.

This work performed aimed at developing a methodological framework to inform the integration of CM into MCDA in the context of assessing hydrogen technology scenarios with respect to their social acceptability. As this decision situation consists of a broad range of stakeholders with possibly conflicting and unstructured views, it appears difficult to make a good or rational decision in such a social mess. In such ill-defined decision context, it was crucial that the related decision problem is structured in order to build consensus among stakeholders' objectives. However, structuring this problem needs to take specifically into account how to construct such a consensus and this is the reason for which CM comes into play.

3.3.3.3 Combination of SCA and MCDA

As seen in the previous chapter, SCA consists of four modes – Shaping, Designing, Comparing, and Choosing. SCA focuses on key uncertainties (about related areas, environment and values) and analysis of interconnected decision options. SCA parallels MCDA – shaping and designing highlight key choices and comparing evaluates these using a simple form of multicriteria evaluation. Focusing on a case study will be helpful in understanding how SCA and MCDA are combined in practice.

Multidisciplinary Optimization in Mission Analysis and Design Process (Amata et al, 2004)

The aim of the study presented by the authors is to identify an efficient approach to tackle conflicts at different sub-systems levels, arising in space engineering during the whole design activity. This document focuses on a typical scenario that the system engineering has to deal with and is oriented to introduce an advanced Multidisciplinary Optimization (MDO) methodology. This work proposes a new methodology for tackling multidisciplinary optimization problems in space design characterized by non-collaborative entities. One of the main reasons to search for new methods and approaches to solve MDO problems is the increasing complexity of the engineering systems. Since solutions time for most analysis and optimization algorithms increase at a super linear rate, the computational cost of MDO is usually much higher than the sum of the costs of the single disciplines represented in the MDO itself. The WATS (Water vapor and temperature in Troposphere and Stratosphere) mission has been chosen as basic case study.

In order to address the problem, the authors proposed integration of three approaches: Neighborhood Search, Game theory and MCDA. However, for the MCDA structuring phase Strategic Choice Approach was used. The Strategic Choice Approach can be used to elaborate a finite set of ‘admissible’ alternative solutions (or possible actions) and to structure the adequate multicriteria evaluation model. The second, an outranking method, compares possible actions in relation to their evaluations on the different criteria and to the decision maker’s preference The decision problem, in relation to the case study was not enough structured for the application of a multicriteria method as ELECTRE. A set of possible solutions was not defined and therefore a consistent family of criteria could not be identified and developed. The principles of the Strategic

Choice Approach to planning under uncertainty (Friend, 1989) can be used to elaborate several schemes of problem shaping and design, to incrementally define a finite set of admissible alterative solutions and to support in the structuring of the multicriteria evaluation model. The Strategic Choice Approach is a methodology that can be used as a useful complement of the Multicriteria decision analysis in complex problems. It is applied to the WATS mission as an example of problem structuring that is not so different from the usual logic of an MD project co-ordination, complete, logically correct and easily documented.

Considering all the different involved sectors (Mission Analysis, Power subsystem, Propulsion subsystem, Configuration and Pointing subsystem, Launch Strategy) as interconnected Decision Areas (DA) is the first possibility of action. A list of decision options can be proposed for each area and analyzed. The decision options of all the DA can be combined in a finite set of alternatives that in this case are the different project typologies. A check of the mutual compatibility between each pair of options reduces the number of the possible typologies, but if there are many DA and decision options the number of the compatible combinations is normally very high and the comparison of these typologies and the choice of the best solution may become difficult.

Strategic Choice Approach proposes a second possibility of distinguishing between 'basic' project characteristics (in terms of prominent DA) and other characteristics, in terms of decisions that can be examined in a second time, and developing a sequence of modes of activity – usually referred to as 'shaping decision areas - designing possible solutions - comparing options and global solutions - choosing'. This sequence is not linear, but normally cyclic and aims at:

- The elaboration of sequential sets of admissible solutions,

- The control of the uncertainties that make the decision difficult or impossible,

- The development of a validated evaluation model,

- The selection of the better solutions and the exclusion of the worse ones,

- The convergence towards the best solution for the decision or the use of an analytical multicriteria method to evaluate, compare and rank the set of possible solutions that the methodology produced at the end of its application.

The prominent Decision Areas, which are related to the different involved sectors, in this case could be:

- 'constellation deployment' (above all in relation to the ascending node separation);

- 'the type of launcher', 'the number of satellites for each launch' and 'the number of launches';

- 'configuration and pointing strategy' (with propellant type and solar array and battery type)

The Strategic Choice Approach suggests a multicriteria synthesis of the different comparisons that is more qualitative than analytical. The aim is discriminating the really different situations. An analytical comparison (for instance with ELECTRE) is required to distinguish "similar" situations. This limited set of solutions is the first result of the Strategic Choice Approach to the problem. The second is the incremental definition of an evaluation model that includes the costs, the waiting time and the number of occultation as possible criteria. A new and more oriented to the pointing strategy criterion could be useful. The set of alternatives were analytically evaluated on the three (or four) criteria, after a phase of parameter optimization, and an ELECTRE method was used to arrive at the best solution.

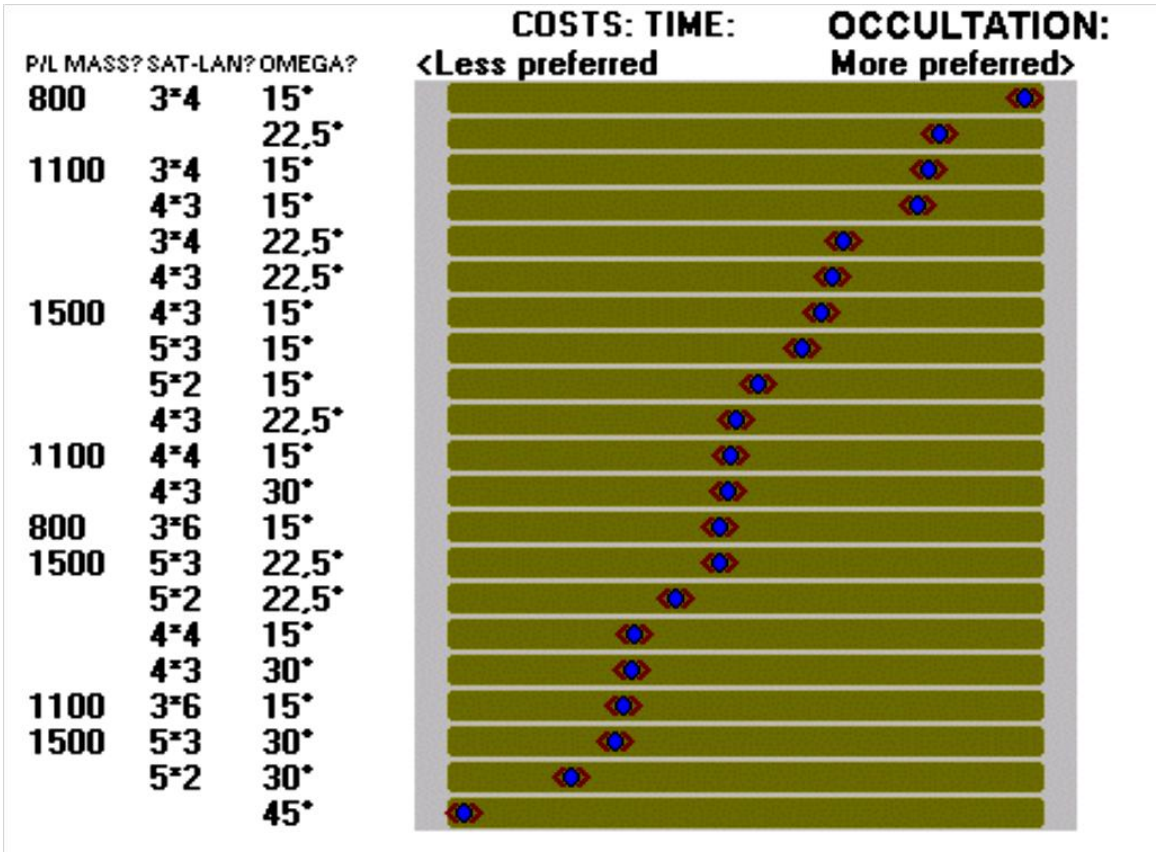


Figure 3.7: Result of first step SCA (Amata et al, 2004)

3.3.3.4 Combination of Drama Theory and MCDA

Drama theory is appropriate to use in multi-party contexts, where the outcome is dependent on the inter-dependent actions of the parties and it seeks to identify stable options. Drama theory is linked with MCDA in terms of requiring possible futures to be ranked according to preference, which is done holistically. Again we will look at a case study in order to analyze this combination.

The majority of current private and public problems are messy, involving, among other complexities, many dimensions and several actors with differing perceptions and preferences. The complexity of the resulting decision process arises in part from the need to simultaneously consider the individual process, the multiparty process, and the many linkages and interdependence between the two. In this each party needs to pay attention to the quality of solutions according to both their preferences and their political feasibility. MCDA applied to multiparty decisions has generally utilized one, or a combination, of the three general procedures: sharing, aggregating or comparing. In many situations, however, decisions involve more than one actor or decision maker for whom the implicit homogeneity assumptions of traditional MCDA are untenable. There is no agreed set of options for consideration and individual parties to the process have very different concerns. Aggregating is not a viable option because nobody has the power to enforce it and comparing is insufficient to push the process towards resolution. In these multiparty decisions, the group MCDA methods are far from representing an exhaustive formal approach and a definite response to the problem. When decisions involve different stakeholders and a certain level of conflict, the interdependence of individual choices and the resulting strategic aspects are crucial issues, which should not be overlooked. In such cases, the underlying value systems and the results of the individual multicriteria analyses must be seen as input to the subsequent multiparty evaluation process, which seeks a solution which, above all else, is politically feasible. In contrast, drama theory concentrates on the analysis of the (strategic) interactions among actors in pre-play confrontation and on their evolution towards resolution of the underlying problem and conflict. In this context, the common elements of a frame are defined beforehand and appear in the scene-setting phase, whereas positions, threats and promises are defined outside of the model and progressively materialize in the build-up phase with the help of dialogue among characters. Drama theory sets itself beyond the individual decision process, which leads to the definition of the actors' positions and the choice of their threats and promises; and above the underlying individual process of comparison and evaluation of the different futures set on the negotiation (Bennett, 1998). This is the result of the theoretical focus, and also of the explicit desire to keep the common reference frame as simple as possible.

Combining MCDA and conflict analysis: an exploratory application of an integrated approach (Losa and Belton, 2006)

The aim of this work by Losa and Belton is to develop an approach that extends each of the existing methodologies and provides an integrated framework for multi-actor, multi-criteria decision aid. The strengths, weaknesses and complementary characteristics of MCDA and drama theory are considered in this work. Drama theory outlines the evolving character of the game, propelled especially by endogenous forces. Among them, the focus is on the emotions of the actors involved in the confrontation, and on the so-called paradoxes or dilemmas of rationality. There are six situations that may give rise particular to emotional tensions in pre-play

confrontation, possibly triggering preference changes that may lead to an evolution/resolution of the confrontation.

The authors describe the case of a privatization process affecting a regional public authority. This authority is a part of the organization, which provides a social service, and is anticipating transfer to a Foundation. The initiator of the service has retired after 20 years in post and has been replaced by a new manager who is tasked to effect and accompany the transfer on a part-time basis. The new manager was motivated to accept the post by its high public relevance, combined with the opportunity to shape the service according to his 'view'. His first task, with a deadline of the end of the year, is to prepare a plan for the future activity of the service in order to secure funding from the regional authority (RA). If this is not successful, the transfer to the Foundation will lead to job losses and poorer working conditions for the remaining staff. The assistance of the experienced and esteemed staff is essential in developing a sound plan. However, the staff has always been in conflict (although somewhat latent) with the RA about the nature of the service and the way it should be provided. The RA is highly focused on the cost efficiency of the service and its compliance with underlying legal and formal norms. On the other hand, the staff, in common with the new manager, is more concerned about the effectiveness of the service in terms of the quality of support provided to beneficiaries. Although sharing this focus on effectiveness, the staff is skeptical about the manager's ideas on how it should be achieved, which characterize his philosophy for the service (one party favors legislation while the other education). These concerns, however, are outweighed by fears of the privatization process, which drive their desire to ensure, through their participation, the development of a plan acceptable to the RA. Another source of confrontation between the staff and the manager was supervision.

Using the confrontation analysis, the authors identified the dilemmas in the situation. The manager faces an inducement dilemma and a deterrence dilemma against the staff as they prefer that he resigns. The staff has only one dilemma, related to the impossibility of trusting the Foundation to keep their joint position. Their trust dilemma is the other side of the coin of the cooperation dilemma facing the Foundation. The Foundation has a positioning dilemma. It would prefer to stay apart (the two opponents solve the situation by themselves), but to avoid an embarrassing public exposure of the conflict it joins the position of the staff. According to drama theory the characters want to get rid of their dilemmas and the related emotional tensions, to reach a common, stable situation from which no one is tempted to defect. This could be achieved by one or the other character abandoning their position, by changing part of their strategy, or by changing their preferences.

After highlighting the dilemmas, the authors translated them in form of a value tree, thus ‘zooming in’ on the problem situation using the lens of multi criteria. The value tree identifies the important aspects of the problem as perceived by the manager and staff. The main branches of the tree relate to the three elements of the conflict, the content of the plan, the process by which it is achieved and the consequences of potential threats.

The work by Losa and Belton presents a first exploratory step into the provision of an integrated framework for multi-actor, multicriteria decision aid through the linking of drama theory and MCDA in the analysis of a live issue. The analysis of potential conflict is a fundamental element in the provision of decision aid in a situation that involves several parties with shared power. In situations that could be classified as coercive, as opposed to pluralist, the use of MCDA, from a unitary perspective and without consideration of the broader issues, is likely, at best to provide a partial analysis of the situation and at worst a misleading one. Thus, the integration of MCDA with conflict analysis opens up a wider field of application. Conversely, the analysis of conflict can be extended by the use of MCDA to provide additional insight into the definition, analysis and possible avenues to resolution of the conflict.

Definition: the identification of relevant values/beliefs is a fundamental step in understanding the key issues underlying the conflict and the extent to which these may be perceived differently by different parties. Furthermore, an appreciation of the preference structures of the parties enables each character to better define its own position and threats. The problem-structuring and model-building phases of multi criteria analysis, aided by appropriate tools for visualization, are focused on developing this understanding.

Analysis: The multicriteria evaluation of the different futures can enable the actors, or a third party mediator, to develop and come to a deeper understanding of their preference structures. This will assist in the identification and understanding of dilemmas, and appraising the strength of these. The analysis forces hard thinking and ensures that all relevant factors are kept in focus.

Resolution: The detailed analysis of the characters positions, threats and dilemmas in terms of their values reveals critical issues and highlights the weak points of their strategies. This explicit representation of information, differing perceptions and values represents a rich knowledge base from which rational arguments in the common interest can be developed and elaborated. This can foster creative thinking, preference change, or the build-up of a supra-character, which may lead to the transformation from confrontation to collaboration. The nature and extent of a change in preference that may lead directly to the resolution of a dilemma, or to a change in position which then achieves the resolution, is highlighted by the multicriteria analysis. It may be that preference differences are marginal and a greater emphasis on a specific factor is all that is required to bring about the change, or it may be that the differences are substantial and may be resolved only by appeal to hitherto unconsidered factors, or by the creation of new potential futures.

Part 2
Applicative Part

Chapter 4
An improvement in decision aiding process

4.1 Introduction and purpose

Several critical elements (such as uncertainty, complexity, lack of structure etc) limit the use of analytical models and methods in problem solving and decision-aid in practice. What are the main difficulties encountered in a collaborative environment during the application of problem structuring methods? The main issue encountered is the presence of a power factor in a group which means that a powerful manager can influence the others so that the diagrammatical presentations don't represent the right point of view of the overall group. This issue has been discussed in Flood and Jackson (1991).

Another problem is connected to the role of the facilitator or the expert. The question arises that what is the distinction between an expert and a novice? Are there any set of rules available that can help us to answer this question? What are the challenges faced by a facilitator during an intervention? Keys (2006, 2007) provide the answers of these questions by describing types of knowledge that an expert can utilize. (Keys, 2006) provides the idea that experts in any field deploy six types of knowledge that were first presented by (Fleck, 1998): formal knowledge, instrumentalities, informal knowledge, contingent knowledge, tacit knowledge, and meta-knowledge. Each type of knowledge is applied according to the ideas and view of an expert and the form and content of this knowledge alters as expertise is gained. The nature of the knowledge held by an individual and how it is deployed significantly determines whether that person is considered to have expertise. Keys also highlight the critical role of experts and the challenges faced by them during an intervention. According to Keys one of the challenges faced by the facilitator is to identify the scope of the problem situation and how to manage it. Based on his knowledge and prior experience, the facilitator recognizes certain elements in order to make a network. The next problem for analyst is to continuously monitor all these elements for the network developed and to keep the focus on the main problem. Another problem for an expert is to address the uncertainties present at different stages of the network and work for a negotiation between all actors involved.

Keys (2007) proposes a community of academics and practitioners, that should be developed to facilitate the diffusion and use of problem structuring methods, and an actor network framework that can help facilitate the decision making process. *"The initial representation or conceptualization of a problem is so crucial to its subsequent treatment that one is tempted to say that the most important as well as most difficult issue underlying the subject of problem*

solving is precisely 'the problem of how to represent problems.'" (Mitroff & Featheringham, 1974)

In relation to this situation, our idea is to develop a community, similar to the proposal of Keys, with the aim of integrating competences on how soft and hard OR methods may be used and integrated (sometimes with non-OR methods) to face complex and unstructured decision situations, in order to develop methodological skills that could effectively facilitate the analyst's work. This community could work starting from the methodological aspects that Keys (2007) proposed to test if they are useful to improve knowledge acquisition and transfer and/or to better define or improve them in relation to our research question.

Each new member of this community may be involved, at the start in relation to a specific old intervention, in an investigation project that will be developed, in relation to some cases and their modelling processes, which have been developed in real organizations, by means of a specific technical approach and with the support of a multi-methodology with formal tools that propose a limited quantification within a systematic framework.

The Keys' proposal (2007) is to adopt the logic of actor network theory (ANT) (see Appendix) to facilitate knowledge transfer and creation. In relation to this logic, an intervention may be considered a project that has to be planned, managed and controlled by means of an actor network. All the involved actors, that assume identities according to prevailing strategies of interaction, have to be identified and defined in terms of identity (i.e. ambit in which they mostly act or are acted on in the networks of practices) and interactions in the network (including the interactions by which they are observed, named). The actors can be both human and non-human and the last may be influencing factors or entities (artefacts or devices, such as images, databases, standards, rules of law, norms, models, texts, journal articles, conference papers and presentations, grant proposals, patents and so on).In this investigation important non-human actors are the specific components of a methodology or of a personal approach to the problem. The actors can be connected with other human or non human actors by means of the main activity contexts (such as data, knowledge and information acquisition to identify (1) the main aspect of a problem, structuring (2) of the problem situation, development (3) of representations, models, applications and so on, evaluation and control (4), communication (5)) that characterize the aim of each specific activity in the intervention and often also the activity. In some cases an activity can be different from its aim. Some examples are the development of a model to structure the problem or to communicate with the stakeholders.

Therefore our operational idea for the investigation is a procedure at two phases, the first for the creation of a knowledge base for the second phase and the second of interaction between analyst and the author of the paper that describes an intervention case. The first phase includes three

activities that are finalized to facilitate the successive interaction with the "human" source of knowledge:

1. Reading of a paper in relation to a case, in order to study a first intervention in relation to a problem situation and create a communication space for the direct interaction with the author and new member of the community;
2. Elaborating a tentative actor network that represents the involved actors and their relationships, to be discussed in the interaction phase;

3. Elaborating a synthesis of the described case, in relation to a framework that includes three main aspects (the structuring level of the situation, the present element of informal knowledge about the case and the adopted approach, the role of the methods and the included formal knowledge).

The interaction phase will be developed by means of a set of meetings, using e-mail, Skype or other tools, or face to face, that have to allow a collective analysis to be made of the elements produced in the first phase (the framework and the actor network), in order to clarify, modify or improve the first knowledge structure and, above all, to create a communication space and a common language. A free interview (using Skype or in presence) should therefore been used to better understand how the expert acts during the realization of the interventions, with the aim of understanding if the acquired knowledge may be generalized as process knowledge, usable in general processes of project development.

4.2 Proposal of framework

The framework that synthesizes a reading of a specific intervention, in relation to the aspects Keys proposed, has been made according to the aspects: structuring, instrumentalities and informal knowledge. The first tentative framework is shown in Figure 4.1

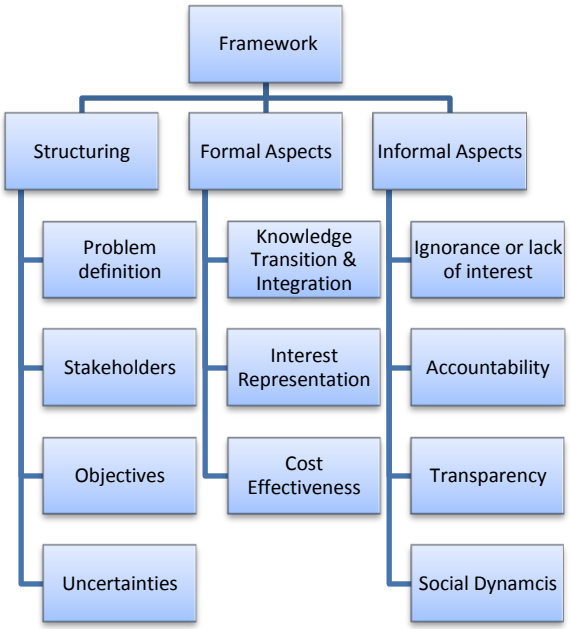


Figure 4.1: Tentative Framework

However, this framework was not deemed as useful because it is too rigid and doesn't take into account the interrelationships between elements. Structuring should be connected with the formal and informal aspects which allow us to change the structure at a later stage depending on knowledge acquired. Therefore, a new framework was discussed and it is represented below:

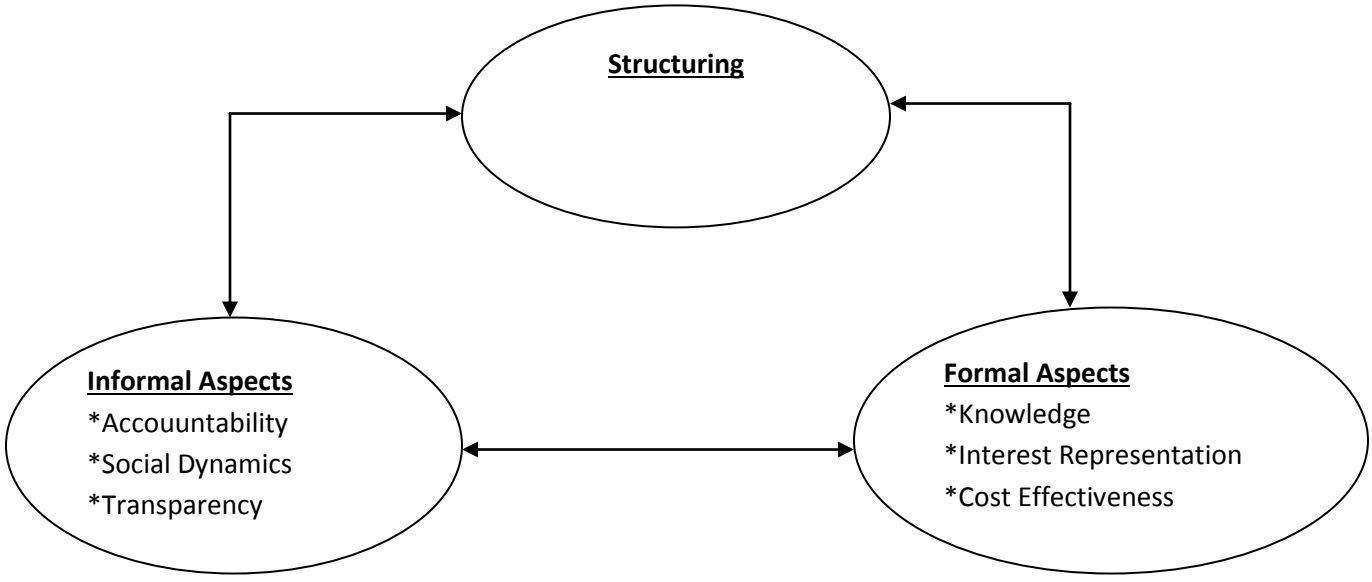


Figure 4.2: Tentative Framework (Number 2)

This framework represented in Figure 2 represents a much more flexible framework. All the three main elements are interconnected which gives us the opportunity to change not only the structuring elements but also the formal and informal aspects if the need arises. This framework provides good consistency with the Keys proposal.

But in order to provide some new factors that are considered important, the idea was to focus on structuring, elements related to competence and the elements related to administration. The main focus was on the studies involving some intervention, so it forms the centre of our framework as shown in Figure 4.3.

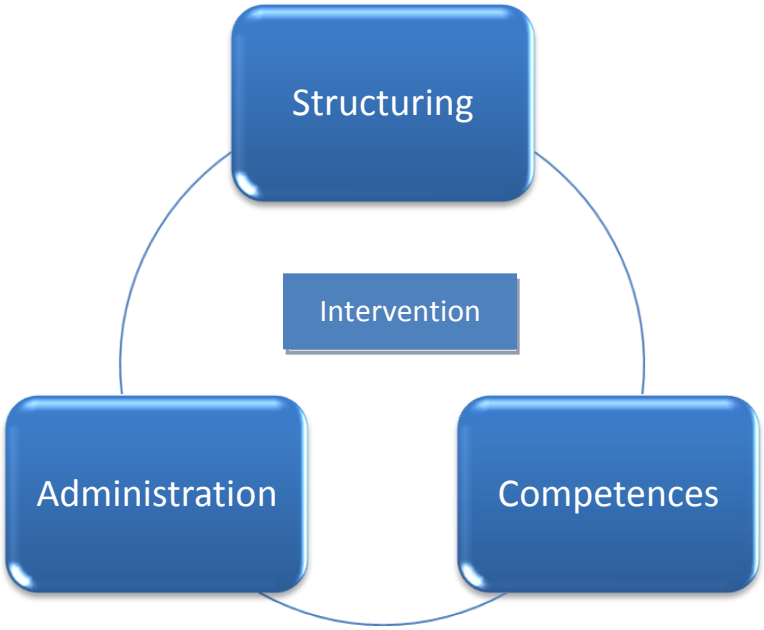


Figure 4.3: Final Framework (Number 3)

The description of each element is presented in the following table:

Table 4.1
Elements of Framework and their description

Element	Description
Structuring	1 – Problem Definition, Goals, Stakeholders, Uncertainties

Conception Of Competences	1 - Knowledge Transition & Integration 2 – Interest Representation 3 – Past Experience 4 – Social Skills 5 – Method Selection
Conception of administration	1 – Cost Effectiveness 2 – Social Dynamics; 3 – Transparency. 4 – Regulation

4.2.1 Structuring

The basic idea is to identify the main aspects that describe an intervention in relation to the need of structuring a problem situation. Then the aspects can be formalized into attributes for which levels or evaluation states should be defined and connected with level and nature of the present uncertainties. A first list of questions for the community is generated, to be used before and/or during the interaction phase.

As far as structuring is concerned, the main aspects related to structuring are described with the hypotheses of attribute definition and some possible questions (For more detail, please refer to chapter 1). According to Ackoff, **"Every problem interacts with other problems and is therefore part of a set of interrelated problems, a system of problems…. I choose to call such a system a mess"** (Ackoff, 1974). Ackoff also described the nature of "messes". According to him, **"a mess is a system of constantly changing, highly interconnected problems, none of which is independent of the other problems that constitute the entire mess"(**Ackoff, 1979a). As a result, no problem that is part of a mess can be defined and solved independently of the other problems. Accordingly, the ability to manage messes requires the ability to think and to manage systemically.

Problem definition is an important part of problem structuring. Charles F. Kettering (1876 - 1958), a US electrical engineer & inventor, once said: **"A well-defined problem is half solved"**. Similarly, Einstein said that if he had **one hour to solve a problem, he would spend 55 minutes to define the problem and 5 minutes to solve it**. One of the main usefulness of effective problem structuring is that it facilitates the correct definition and representation of a problem. If problem structuring is done ineffectively, it results in a very narrow definition of a problem and hence the alternatives are limited (Watson, 1976). Problem definition aims to eliminate or reduce misunderstanding and concretize too generic requests and descriptions of the problem situation. The correct identification of stakeholders, along with their roles and

contributions in the decision process and their knowledge and vision of the problem, is an important part of structuring. The distinction between a collaborative, a non communicative or a conflicting environment is important and has to be made at the start. Structuring should be developed involving stakeholders, but in some cases this approach is difficult or impossible.

Structuring requires a clear identification of the objectives in relation to the problem and the intervention. There should be a coherent understanding about the objectives. During an intervention, the objectives may change or new objectives may emerge but it is important that they are agreed upon by all the stakeholders involved.

The main research questions are:
what are the main aspects in the definition of a problem? (Goal of the intervention, aims of some specific activities that are required…)

b) How weakness in the problem definition may be recognized? What are the uncertainties involved in the definition?

c) Who were the main actors? Their identification has been immediate and easy? Which has been their involvement (at different level, with different role, power and resources)?

d) Have the views of the stakeholders been taken into account?

e) At the start of the intervention has the problem clearly and completely been defined? If not, how and when the problem has been defined? Have the aims/goal been easily elaborated?

f) What are the main uncertainties? Are they implicit or explicit?

4.2.2 Conception of Competences

4.2.2.1 Knowledge Transition & Integration

Knowledge transition is the process of transferring knowledge regarding the problem situation to all the stakeholders involved in an intervention. The existing knowledge is complex, often conditional, certain outcomes can be reached by various options and the available information is often incomplete. (Keys, 2006) provides the idea that experts in any field deploy six types of knowledge that were first presented by (Fleck, 1998): formal knowledge, instrumentalities, informal knowledge, contingent knowledge, tacit knowledge, and meta-knowledge. Each type of knowledge is applied according to the ideas and view of an expert and the form and content of this knowledge alters as expertise is gained. The nature of the knowledge held by an individual and how it is deployed significantly determines whether that person is considered to have expertise. Depending on the problem situation, the relative importance and availability of these types of information vary. After the knowledge transition, it is necessary to integrate it. Modelling is used to integrate information in 'hard' problems but it is difficult in a multi-

disciplinary ‘soft’ problem situation. This is because in different areas, the types of risk and uncertainties involved are different. The visual representations involved in PSMs are often used in order to integrate and also for the purpose of transition.
The questions to be answered are:
a) How can different types of knowledge/ information (personal, different domain) be clearly explained to all stakeholders?
b) How are the different types of knowledge integrated within the approach?

4.2.2.2 Interest Representation

In the decision making environment, it is necessary that the viewpoints of all the stakeholders are represented. Just the ‘inclusion’ in the intervention is not enough as the viewpoint of everyone should be taken into account. This means that the viewpoint of all stakeholders should be taken into account. The issue is whether all relevant interests and affected stakeholders are known, included and/or represented in a way to assure their equitable participation in the process. It is by no means trivial to identify all the interests involved in a specific problem situation, especially when taking into account that many decisions have far reaching consequences with regard to time and cost.
a) Are all relevant interests included or at least represented?

4.2.2.3 Past Experiences and method selection

For an analyst the ability to draw upon previous experiences and use them is an important factor that can be used in intervention process. The analyst’s previous experience of working with the client and knowledge of how similar processes had been effective elsewhere provides insights on the present situation and suggests which participative and facilitative approach can be adopted. The selection of a particular methodology is also related to experience. The analyst makes choices about which PSM to adopt and implement.
a) How are the methods selected for different problem situations?
b) What is the role of previous experiences in interventions?

4.2.2.4 Social Skills

The analyst requires social skills for analyzing the interactions in the intervention process. The organizational, social and cultural norms have to be understood and realized by the analyst. The research questions for the community related to social skills are to find out the relationship between having good social skill and successful interventions.

4.2.3 Conception of Administration

4.2.3.1 Cost Effectiveness

The idea of cost is important as the literature available doesn't discuss the cost effectiveness of interventions. This section in our framework includes questions on how well a method is suited to find cost-effective resolutions for the conflict, i.e. how well it takes into account the available means and is able to help elucidate the costs and effects of different resolutions.

a) Is the cost-effectiveness of the proposed solutions or suggestions represented/ indicated or at least considered.

4.2.3.2 Transparency

The decision making process should be transparent. This means that the different views are completely understood and clear for all involved. Making use of the competences, an analyst can help to make the whole process more transparent to all the actors involved so that they have a thorough understanding of the situation and of the concerned problem. Moreover, in an intervention there may be some participants who are not motivated or have no good idea about the problem situation. It is important for an analyst to consider these participants and try to motivate them in order to have their point of view concerning the situation.

a) Are rules and assumptions transparent to insiders and outsiders?

4.2.3.3 Social Dynamics

The social dynamics are relevant not only from the point of view of pragmatic ethics, considering that the confrontation of different values and ways of behaviour in specific conflicts (i.e., in situations that are important for the people concerned) gives the possibility to change old, accustomed ways of thinking and of behaviour into new, more adapted ones. The decision-making process can have considerable impact on the relationships between the relevant actors; this relationship might even be constituted through the decision-making process itself. Social Dynamics allow construction of mutual trust and understanding of the interests involved leaves room for the participants to readjust their position in a conflict and thus increase the range of outcomes considered acceptable. Hence, for the analyst it is important to have social skills in order to act as a suitable facilitator during the intervention process.

a) How do social-dynamics affect the relationships of the actors?

b) Whether social dynamics allow for the changing of perspectives or learning taking place?

4.3 Case Studies

To discuss the questions presented in the last section, we will take example of some papers. These papers with a focus on practical applications in policy, environmental and disaster management provided us with knowledge and the guideline in order to proceed. The main focus

was on intervention process involved and in some cases PSM were used but not in all. Structuring intervention analysis was the main concern through the use of a framework and questions were put forward to the authors of the papers. The community of researchers formed and their papers with the context, aim and the methods used are presented in the following

Table 4.2
Community and the papers discussed

Case	Context	Aim	Method(s) used
1. M.F. Norese (ITALY)	Strategic Policy Planning	Location of waste-treatment plant based on set of criteria	MCDA (ELECTRE III) and some elements of MACRAME
2. Diana Rolando (ITALY)	Strategic Policy Planning	Selection of a right point for road to pass keeping in view the environmental and financial impacts	SCA- In order to structure the problem and identify uncertainties
3. Gabriella Balestra (ITALY)	Procurement, Health	Quality assessment for the selection of equipment for a hospital in Torino	AHP
4. Alessio Ishizaka (UK)	Safety	To prevent failures by an optimized and effective resource allocation	Fault Tree Analysis, Critical Tree Analysis, AHP, Knapsack Optimisation
5. Jean-Philippe Waaub (CANADA)	Energy Policy	The coherence of federal and provincial policies and of energy and climate policies in Canada	SWOT
6. Irene Abi-Zeid (CANADA)	Tourism Planning	To present a multi-criteria classification approach for identifying world climates	ELECTRE TRI-NC
7. Francis Macray (FRANCE)	Agriculture, Environment	To assess the agro-environmental risks at different spatial levels	ELECTRE TRI-C with ArcGIS, AZOTOPIXAL method

4.3.1 ELECTRE III as a support for participatory decision-making on the localization of waste-treatment plants

M. F. Norese

Land Use Policy 23 (2006) 76–85

Abstract

This paper proposes an analysis of this participatory decision process and synthesises the difficulties and results of the Multi Criteria decision aid intervention.
The paper deals with locating an incinerator and a facility to store ashes and other wastes is a long and complex process in Italy. The District of Turin faced this situation by choosing a participative approach to the problem and by using multi-criteria (MC) analysis as a support for a specific phase of this decision process. A group of 45 decision-makers (local authorities and representatives from the different communities that were involved) worked together with a facilitator group for 16 months to identify the criteria judged relevant to analyse the consequences of the location of a plant. Two MC models—one for the incinerator and the other for the waste-disposal plant—were elaborated and an ELECTRE method used to compare sites and rank them with the aim of selecting the best sites to activate an Environmental Impact Assessment procedure. A team made up of analysts from different organisations supported this work from a technical point of view.

Defining the network

In 1998, the District of Turin, which is in charge of policy planning, formulated a programme for waste management that divided the territory into three areas (north, west and south-east), each of which would have to be responsible for its own waste management. In March 2000, the District of Turin activated the NRDS (‘Do not refuse to choose’, NRDS) as a participative decision process in the global process. It proposed a form of participation that was applied for the first time in Italy: a non-institutional commission with decision capacity. A concerted group of experts in mediation, participative processes and MC aid (the NRDS facilitator group) was asked to create the commission and to facilitate the process. The District of Turin asked the commission to identify location conformity criteria for all the possible locations (the 38 sites which were initially identified by different sources) and to use an ELECTRE method to rank these locations. The commission’s work resulted in the classification of the sites and in the guidelines of a contract between the involved actors and the future plant manager. The guidelines concerned guarantees, safety, control and compensation.

Managing the network

Thirty-five meetings were organized over a period of 16 months (from July 2000 to December 2001). Two MC models were developed during the commission meetings, the first in relation to the location of the waste-disposal plant (nine actions or feasible location sites and 14 criteria) and the second in relation to the location of the incinerator, with 13 actions and 13 criteria. The

author led the operational part of the meeting, while the mediator and the Vice President of the District of Turin led the 'contentious' part of the meeting (criticism of the program for waste management, general requests and observations, protests, threats, debates on the alarming declarations in the newspapers about the nature of the decision process and the role of the commission, consequences of the contemporary political elections on the commission).

As there were various contradictory views present in the meeting, the structuring of the problem proved to be a long task. But this time spent led to a reduction in ambiguity and uncertainty of the different positions and interpretations. The dialogue produced essential passages from the chaos of the initial multiple positions to a structured and shared modeling phase. The long debate that developed each time in relation to specific contentious positions or interpretations produced an agreement on the criteria modeling results, the shared elements of these MC models. The author made use of cognitive maps in order to reduce misunderstanding, uncertainties and sources of conflict during the first meetings (Figure 3). Then all the proposals of criteria, from the participants, were discussed during the meeting until a decision was made. The structure of the model and each criterion can be considered decision acts of the Commission during the process. (Norese, 2006)

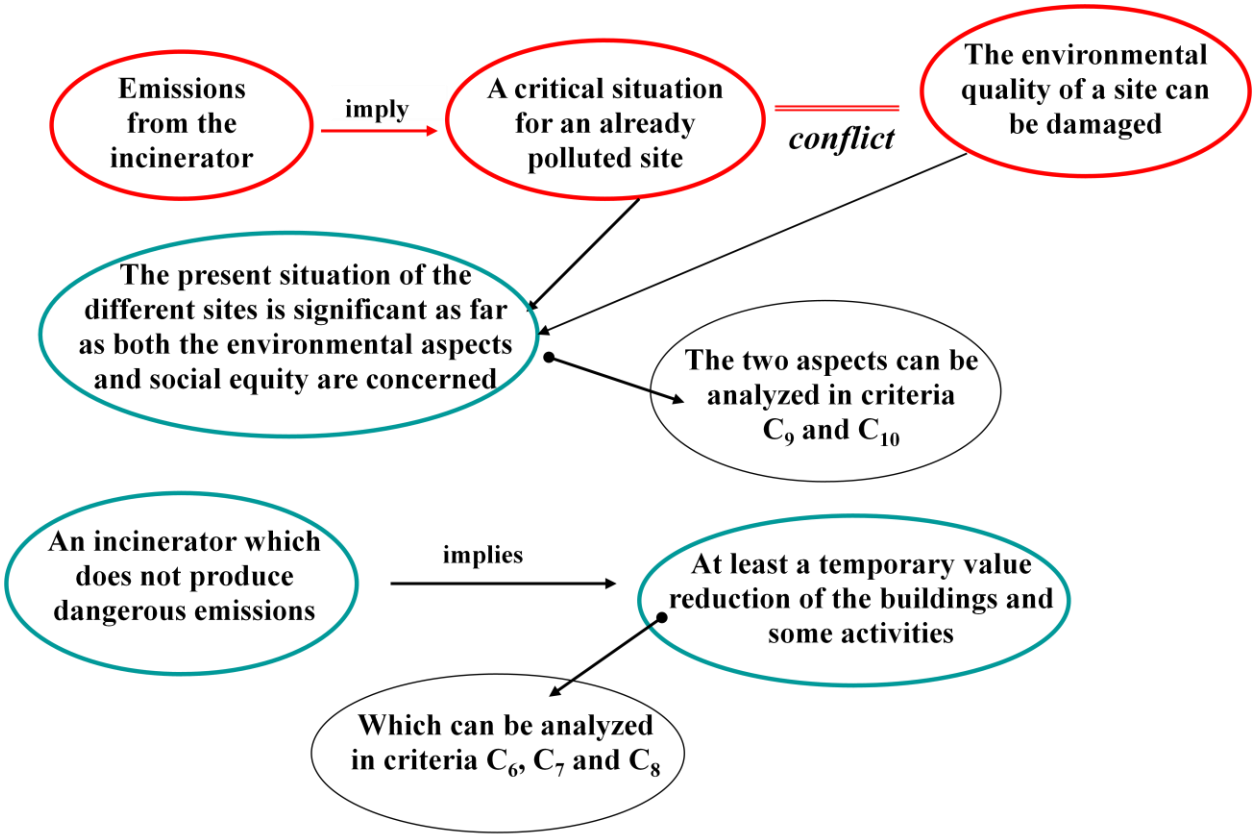


Figure 4.4: Cognitive maps and criteria generation in the case

Dissolving the network

When the list of criteria was completed, the investigation phase started. It included activities, which require time and technical expertise: the site analysis, works concerning indicator elaboration and measurement and report development. These investigation activities are a specific element of each MCDA intervention, but in this case they became more demanding for several related reasons. The two models and the large number of criteria induced 27 investigation projects (one project for each criterion, 14 criteria for the possible waste-disposal site locations and 13 for the incinerator plant locations) and the activation of different technical groups that investigated, drew up technical reports and analyzed all the questions, observations, suggestions and critiques voiced by the decision-makers, i.e. the commission

The significance and use of the parameters (weights and thresholds) that the method uses were analyzed and discussed by the commission. While the dimensions, criteria and action evaluations resulted from a collective process, the weights, in terms of relative importance of the criteria, were instead an individual expression of preference and each non-technical member proposed an individual set of weights. The ELECTRE III method was used to compare and rank the alternative sites, in relation to the shared model and the weights that each decision-maker had offered. The results of the ELECTRE applications were presented in December 2001. Each participant received a site ranking according to his set of weights and a second result, which was the synthesis of all the individual expressions of preference. The first result was proposed to each participant to allow a clear reading (alone or with the group the participant represents) of the solution the individual model generated.

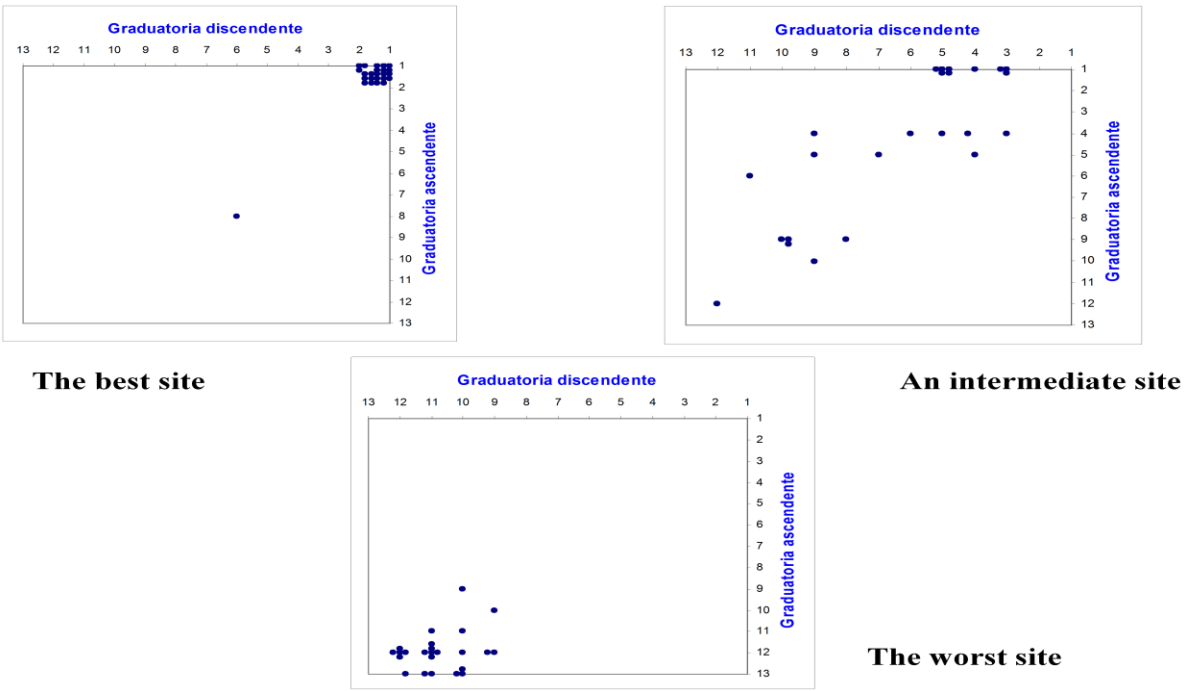


Figure 4.5: Analysis of results

Interview with author of paper Professor Norese

"Problem formulation and model structuring have to be assisted in multi-actor contexts and several different approaches are proposed in literature. Some of them are particularly oriented to MC modeling and can be easily integrated with the MC approach to the problem: the strategic choice approach and MACRAME, which was used (in the paper)."

Q1-Q3 are related to this statement from the paper.

Q1. Why was MACRAME chosen instead of SCA?

Ans. Problem formulation was not assisted by the whole methodology MACRAME but only by the cognitive mapping tool of MACRAME that was used to synthesize the discussion and represent the concepts that were proposed during the first meetings and the relationship between concepts and between them and the problem situation.

A specific logic of model structuring was used when the participants started to propose criteria. The strategic choice approach was not used because it is oriented to problem structuring and in this case the problem was well structured at the start (a complete set of alternatives and the need of multicriteria models to evaluate them and to use an ELECTRE method).

Q2. How were uncertainties clear for you even before the intervention?

Ans. The word uncertainty is too generic and not so consistent with our situation. The experts on participation arranged a simulation of a meeting. The duration was around 30 minutes. The idea was to simulate the environment of the intervention and to give an idea to us, the decision aiding team, about some critical elements that could developed during the actual intervention. This simulation showed the behavioral approach of some members of the Commission and the possible sources of conflict between the participants and/or with us. During the first meetings, in the actual intervention, these communication approaches were evident and in some cases more heavy than in the simulation. But we introduced some simple rules that reduced the difficulties and the misunderstandings of the internal communication.

Q3. Was the integration of the cognitive maps of MACRAME with ELECTRE achieved easily?

Ans. The cognitive maps were used only to demonstrate that different positions, in relation to the location problem, can be included in a multicriteria model. When the participants understood this possibility and started to propose criteria, the maps were used to cluster all the proposals that were in relation to an important aspect. Then a simple logic of hierarchic model structuring was used during the meetings, identifying the main aspects and all the significant criteria of each aspect.

This is not an integration of two methods but the use of tools that support the initial conceptual phase of the intervention. The relationship between members of the Commission and between them and the facilitators was difficult in the initial meetings. At the same time the initial meetings, that did not produce operational results, were essential to improve the communication, for the elaboration of a co-operative attitude and some ‘‘reflective pauses’’ allowed the explicit declaration of doubts and preoccupations and the passage to collective positions and decisions.

“The communication between experts and representatives became difficult and sometimes even critical because it led to open conflict and loss of confidence or misunderstanding”

Q4-Q6 are related to this statement.

Q4. What was the cause of this conflict? What implications it had for the process?

Ans. Now I prefer another word: not conflict but difficult communication, in some cases, or disagreement. It was mainly because this was the first experience for the technical groups that investigated, to be involved in a participative intervention. The interaction with a participation process was completely new for almost all the involved Services and unusual for the Regional Agency and the University Departments. Secondly, for some technical experts who are used to using hard models, it gets difficult to understand the need of transparency of the Commission. For others, who are used to speak and explain their position, it gets difficult to create a clear but formal report.

The commission required an explicit presentation of their investigative approach and the nature of any possible results. Each of the technical groups proposed a different methodological approach and in some cases the Commission agreed with these presentations, while in others the reaction was clearly negative and they required a better and deep new analysis. The implication of this kind of action was loss of time but mainly a better and a shared model.

Q5. Did the relations between the Commission and the technical groups affect the process?

Ans. The relations between decision makers were difficult only in the first meetings, then they became co-operative and clearly oriented to obtain good and transparent models and evaluations, and a clear result.

There was a tentative of breaking the commission, from an external actor, by means of one or some members. The tentative was blocked by the reaction of some other participants and a technical proposal of the facilitators.

There were 2 people present in the intervention who only wanted to sabotage the decision making process. It was not clear during the intervention, but their action produce only loss of time. Only at the end they declared their real aim.

Q6. Did their behavior effect the decisions made?

Ans. Their only effect was a loss of time. They had no effect on the decisions made as all the rest of participants were interested and were in majority. 2 people who wanted to sabotage the process couldn't effect the final decisions except wasting time.

Q7. How can the cost-effectiveness of the intervention be measured?

Ans. The main weakness is the length of time required for the interventions. Main investment is in the form of time. 16 months were spent in intervention which is a long time. As far as cost is concerned, there was a cost only for the facilitators but that is acceptable, because the produced information was used in the Environmental Impact Assessment procedure.

Q8. Why did the district suggest using ELECTRE method? Could any other method be more useful?

Ans. Initially they required an ELECTRE method for use, because they had the occasion to know ELECTRE II, but after taking into account the difficulties in terms of nature of the evaluations I used ELECTRE III.

4.3.2 Multicriteria decision problem structuring: the Strategic Choice Approach in the context of public projects in Italy

Diana Rolando

Special issue on Multicriteria Decision Aid Methods and Applications
(Accepted for publication)

Abstract
This paper applies SCA and MCDA approach to a policy planning project in Turin. During the first phase of complex plans it is necessary to analyze uncertainties and risks associated with the project, to define strategic decisions as well as concrete solutions. The Strategic Choice Approach (SCA) is a methodology that adopts a multicriteria approach to shape decision problems, design and compare solutions and control uncertainties, in order to assist decision makers from the involved organizations. In this work, SCA has been tested on a complex public project in Turin (Italy), to support the decisions to be taken, the criteria for an ELECTRE application and the uncertainties to be analyzed by all the stakeholders.

Defining the network
The Province of Turin planned to complete the ring road around the city (the "Turin East Ring Road"), but for several reasons it had never come to the end. By analyzing the debate generated on the local newspapers, the author commented "it is evident that the case of the Turin East Ring Road is characterized by a high level of complexity from a technical and environmental point of view, as well as difficult to solve for economic, political and social reasons". In order to address these uncertainties, Province of Turin appointed a feasibility study to a group of experts of the Politecnico di Torino and constituted a work team, called "Steering Committee". In fact the decision to institute the Steering Committee could be considered a strategy finalized to guarantee the political sustainability in the relations with the municipalities; the importance in establishing a clear and periodic dialogue with them was a fundamental starting point in the political management of the transformation plans. The aims were to structure the main decision problem "Where should the Turin East Ring Road pass through?" and to demonstrate how the methodology could support a group of people in charge of taking important decisions during the strategic planning of a complex transformation plan.

Managing the network
The main decision problem "Where should the Turin East Ring Road pass through?" has been structured with the SCA support. The sub-problem structure is synthetically described, pointing out the *uncertainty areas*, the *decision areas* and the principal outcomes resulting from the SCA/STRAD applications. The *alternative options* – related to each *decision area* – and the *exploratory options* – related to each *uncertainty area* – have been structured during the SCA/STRAD applications.

Uncertainty Areas				Prominence	Tractability
1	UE/UR	TRAF_FLOWS	Absence of traffic flows forecasts	high	medium
2	UV/UR	OPP_TOLL	Possible opposition by the municipalities and/or by the citizens about the construction of a totally tolled road	medium	medium
3	UR/UE	ECOFINPLAN	Absence of an economic-financial and management plan	high	high

Uncertainty areas identified using SCA

The SCA, through the four complementary modes of operation of the software STRAD, is a supportive methodology based on a multicriteria approach for a group of people in charge of taking important decisions. In particular, during the *shaping* mode, the decision makers are supported in structuring decision problems and in identifying a series of *alternative options*; during this mode it is also possible to understand that the main decision problem is not correctly defined, pointing out other more urgent and important issues.

Then, during the *designing* mode, the *Compatibility window* helps to exclude the incompatible *alternative options*, further simplifying the decision problems. Other *alternative options* – not feasible or not preferable – could be excluded also during the following mode. During the *comparing* mode the main step is the definition of the *comparison areas*, fundamental not only to order the possible decision schemes, but also to identify the aspects that could much influence the comparison among the *alternative options*. The *comparing* mode, in fact, is also finalized to find out the more significant criteria, in order to use them with other methodologies based on a multicriteria approach. Finally, the importance of the *choosing* mode consists in identifying the possible strategic actions (*exploratory options*) useful to reduce the uncertainty level related to the decisions that are to be taken.

Dissolving the network

This part was not included in the paper as the main purpose was to identify the uncertainties. The SCA could support little groups of people in charge of assist the real decision makers during the complex preliminary phase of analysis, after which it could be better to apply other multicriteria methodologies. STRAD, in fact, helps in defining coherent sets of criteria, a very important step if, for example, it is necessary to apply ELECTRE. One of the principal strengths of the SCA consists really in applying it in a combinatory mode with other methodologies based on a multicriteria approach.

Questions for Diana

“ There was no possibility to manage a real interaction in the context of the Steering Committee...Some decisions were taken considering the stakeholders point of view.”

Q1. These decisions were based on which underlying assumptions/criteria?

Ans. I initially structured the decision sub-problems, the decision areas (and related alternative options) and the uncertainty areas (and related explorative options) on the basis of the results and issues highlighted during the Steering Committee meetings. I attended all the Steering Committee meetings and I also attended all the meetings between the experts from Politecnico di Torino and the Mayors of the involved municipalities.

Once structured, I corrected them by sharing my assumptions with the experts from Politecnico di Torino, since the identified decision problems were especially related to technical aspects.
In order to test a possible SCA application I had to choose some alternative options by simulating the stakeholder's points of view.

There was no possibility to manage a real interaction based on SCA in the context of the Steering Committee because the decision process was already planned and coordinated by the Province of Turin (and I was only a PhD student.....)

Q2. Did the steering committee use any specific method during their meetings with stakeholders?

Ans. No. The meetings were lead by a representative of the Province of Turin, supported by the group of experts from Politecnico di Torino.
In particular, one expert from Politecnico di Torino was in charge of coordinating the relations with the Mayors of the involved municipalities, without the application of specific methods, but just organizing a series of restricted meetings finalized to periodically illustrate the Steering Committee work in progress.

Q3. How did the steering committee structure the problem in their meetings with shareholders if they didn't use SCA?

Ans. The Steering Committee did not structure the problem "*Where should the Turin East Ring Road pass through?*", but debated on a series of problems related to it, without expressly highlighting the relations among the decisions, the priorities and the risks associated to them. That was the problem....
With my PhD thesis I tried to illustrate a possible SCA application finalized to structure the same decision problem that the Steering Committee wanted to solve. For example, one of the result highlighted that the "Toll" sub problem was one of the most urgent decision problem to face, but there wasn't a clear political position in relation to it...Today the problem is still unsolved because it depends on the availability of ministerial funding**.**

Q4. Could better results be achieved had SCA been used? (For example less time or reduced uncertainties)

Ans. At a preliminary stage (before the Steering Committee institution) a SCA application could clarify to the Province of Turin representatives a possible decision process structure, as well as highlight the most urgent decision problems to face and the most prominent uncertainties to try to reduce. Then, at a later stage, the SCA application could constitute a useful starting point to support and induce the debate among the stakeholders.

So, a SCA application could be initially considered "time expensive", but it can orient the management of the decision process and finally bring to a "time saving", since if the decision problems are clearer and the stakeholders are obliged to express their position in relation to them, the decision process can result more rapid and successful.

> *"The application of the SCA methodology, with the support of its software STRAD, presents numerous advantages, above all in particular context – such as the Italian one – in which the stakeholders are not used to debate all together sitting at the same table and before that the process of the transformation plan starts."*

Q5. In your opinion, what are the main reasons that SCA (and other PSMs) are not that proliferated in Italy?

Ans. In Italy there are no laws that regulate the preliminary phase of the decision process. The problem structuring phase is rarely considered because it is not mandatory and because it seems to delay the whole process of the project.

Q6. How, in your opinion, can the use of these methods be improved in Italy or in general?

Ans. Unfortunately, in Italy a process has to be mandatory in order to be considered.

4.3.3 A hybrid and integrated approach to evaluate and prevent disasters

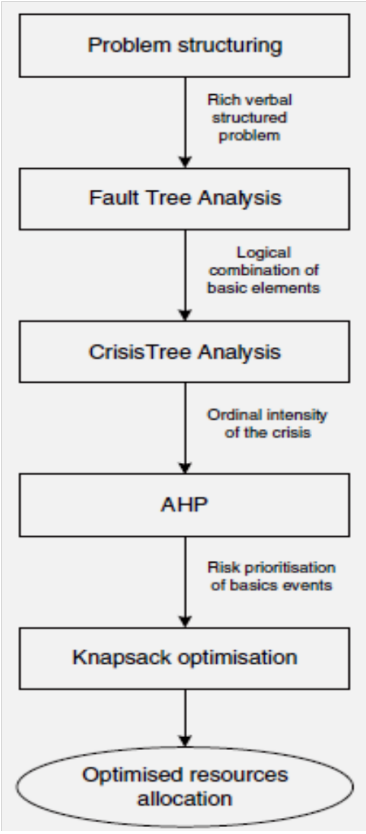
Alessio Ishizaka and Ashraf Labib

Journal of the Operational Research Society (2014) 65(10)

The objective of this paper is to propose a multiple, yet integrated, approach to model and prevent failures by an optimized and effective resource allocation. The proposed approach facilitates the identification and quantification of all possible risks and also suggests the optimal allocation of resources in order to mitigate them. The authors of the paper argue that disasters are complex phenomenon and their modeling using a systematic and logical methodology can help us identify their root causes and may facilitate in allocating appropriate resources to prevent such situations. There are approaches that can be used to model such phenomena but the authors argue that a single approach is insufficient to "provide an effective and realistic analysis to prevent disasters due to its inherent assumptions". Therefore, the authors propose a hybrid approach using four methods in order to optimize a safety investment. The phases of the proposed hybrid approach are:

1. A problem structuring method to build the hierarchy of issues leading to a disaster.

2. A Crisis Tree Analysis (CTA), which graphically displays the combination of facts or basic events that may lead to an accident and an RBD, which helps analysts to visualize the system functionality and critical components.



Methods	*Strengths*	*Limitations*
Problem structuring	The nature of the problem and its structure is modelled with a systematic and complete method.	The method is only descriptive, not prescriptive.
FTA	The combination of the basic events is graphically modelled.	The criticality of the event cannot be quantified.
CTA	The combination of the basic events is graphically modelled and an ordinal severity of the crisis is measured.	A cardinal criticality of the event cannot be quantified.
AHP	The criticality of the basic events is quantified.	The combination (AND/OR) of the basic events cannot be defined.
Knapsack optimisation	The resources allocation is optimised.	Intangible resources cannot be quantified and the combination (AND/OR) of the resources cannot be defined.

3. An adaptation of the AHP in order to quantify the likelihood that a basic event will happen.

4. A knapsack resource allocation, which optimizes the investment in safety measures within each basic event.

The authors have applied the aforementioned methodologies to a Bhopal disaster case study. On 3 December 1984, Bhopal city suffered from the major disaster originated from the Union Carbide Plant (4.8 miles away). Poisonous gases released from the plant left 20000 people dead. Using secondary data from literature, authors have applied their proposed framework to the Bhopal disaster.

1. *The problem structuring* has been performed through secondary data analysis. Since the literature on the Bhopal disaster is very rich, a direct contact with the stakeholders is not necessary. Also, the disaster happened about 30 years ago, so collecting the primary data seems inappropriate as memories have faded and key persons may have disappeared. A secondary data analysis on the Bhopal disaster gives also the possibility to triangulate multiple sources.

2. *CTA* represents graphically the combination of basic events or facts leading to a crisis. The authors identified and graphically represented the events leading to Bhopal crisis.

3. *AHP* was used for the quantification of the basic events identified in the previous step. The pair-wise comparisons were made by authors based on their experience in maintenance, informed by the literature of the Bhopal case and the opinion of an expert in asset management.

4. Safety Investment optimization is done by assuming costs and has been checked using the graphical representation made in CTA. The knapsack Algorithm is used in order to find out what will be the events to consider for maximizing the security in order to avoid the disaster.

In conclusion, four methods have been used in conjunction. This hybrid method permits more realistic and sound decisions than any method used in isolation. This approach has been illustrated with the Bhopal disaster, where the budget allocation problem with their many subjective and objective risk evaluations has been optimized in order to maximize the safety and by consequence minimize the disaster likelihood. The authors have proposed a generic and flexible approach, which can be easily used to prevent disasters.

Questions for Alessio

Q1. Do you think that using secondary data analysis and information is enough in order to structure the problem?

Ans. This depends on the quality of the secondary data. I would be confident enough if there are several independent sources of secondary data which confirms each other.

Q2. What steps were considered and taken in order to address data uncertainties present in the problem situation?

Ans. A sensitivity analysis

Q3. Four different approaches (each for a specific purpose) were used. Why were specifically these approaches chosen? Was it because of familiarity of the methods or were they consistent with the specific problem? Can these approaches be applied to different fields?

Ans. The methods have been chosen because of their strength and complementarity. Yes, the methods generic and can be applied to other fields.

Q4. Do you have experience of working in a group decision making process in an environment where the people involved have different views of the problem? What steps do you take in order to structure the problem in that context?

Ans. I did not have experience where the views were extremely different. This happens frequently for environmental problems but my field is more business.

4.3.4 Selection of new production facilities with the Group Analytic Hierarchy Process ordering method

Alessio Ishizaka and Ashraf Labib

Expert Systems with Applications 38 (2011) 7317–7325

This paper presents the Group Analytic Hierarchy Process Ordering (GAHPO) method: a new multi-criteria decision aid (MCDA) method for ordering alternatives in a group decision. The backbone of the method is the Analytic Hierarchy Process (AHP) which is separated into two hierarchies for a cost and a benefit analysis. From these two analyses, a partial ordinal ranking can be deduced, where three relations between alternatives exist: the preference, indifference, and incomparability. A complete cardinal ranking can also be deduced by dividing the score of the benefit analysis by the score of the cost analysis. Another particularity of GAHPO is the incorporation of 'fairness' when assigning weights to the decision makers. GAHPO has been developed to solve a real case: a selection of new production facilities with multiple stakeholders. By applying this method, we found four main advantages: significant reduction of time and effort in the decision process; easiness for the decision makers to arrive at a consensus; enhancement of the decision quality and documentation with justification of the decision made. In using the proposed method both efficiency and equity are achieved in the decision making process.

Authors have applied the GAHPO method for a case study that took place in a world leading packing company, which had no previous experience in multi-criteria methods. Their approach was based on four phases, each one corresponding to a meeting with the decision-makers of the company, where the researchers where facilitating the decision process.

1. An awareness session on the GAHPO methodology was given. Authors suggest that an understanding of the GAHPO and required inputs is necessary in order to avoid improper use of the method. The advantages of the new decision method were clearly explained in order that everybody accepts it and to avoid reluctance and objections during the decision process.

2. After a brief reminder on the GAHPO, the problem and its possible solutions were clearly defined. Two hierarchies were constructed: one for costs and another for benefits.

3. At the beginning of the third meeting, the participants were given the opportunity to revise the hierarchies. Then, each participant gave its comparisons of alternatives, criteria and participants' weights through a questionnaire. The participants' weights were given by the other group's members. Consistency was checked for each participant.

4. Priorities were aggregated in Expert Choice. A sensitivity analysis was conducted.

GAHPO is both a problem solving and a problem-structuring tool. The cost analysis and benefit analysis hierarchies were developed as two separate AHP models in a half day brainstorming

session with all stakeholders facilitated by the researchers. The cost analysis model had the goal of selecting the alternative with the lowest cost. The benefit analysis model had the goal of selecting the alternative with the highest benefit. Stakeholders are incorporated in the first level of the hierarchy in order to elicit a group preference. The weight of each stakeholders are determined by others stakeholders. A consistency check is applied in order to verify the coherence of the comparisons given by the appraisers. A veto possibility is given to each evaluated stakeholder.

According to the authors, the methodology was easily accepted. The successful acceptance of the proposed methodology can be attributed to the following reasons. Firstly, it helped to describe the problem and break down decision criteria into manageable components. Secondly, it led the group into making a specific decision for consensus or tradeoff. Thirdly, it provided an opportunity to examine disagreements and stimulate discussion and opinion. Fourthly, the process offered an opportunity to perform a sensitivity analysis in modifying judgments. Finally, it made possible to incorporate conflicts in perceptions and in judgments in the model.

After applying, the methodology, the authors proposed the best alternative and all the participants were completely satisfied from the robustness of the results. According to the authors, the advantages of applying a cost-benefit analysis are:

1. Significant reduction of time and effort in the decision process due to a structured methodology.

2. Easiness for the decision makers to arrive at a consensus, because the hierarchy model brings a common reference, which can be debated.

3. Enhancement of the decision quality, due to the consistency check and sensitivity analysis embedded in the GAHPO method.

4. Documentation and justification of the decision made.

Questions for Alessio

"An awareness session on the GAHPO methodology was given… The advantages of the new decision method were clearly explained in order that everybody accepts it and to avoid reluctance and objections during the decision process."

Q1. As an expert/facilitator, what were the main problems faced during the awareness session?
Ans. I did not see any problems, especially because the use of Expert Choice.

Q2. Were there any disagreements about the methodology?

Ans. No, because we were acting as experts and there a good trusting relationship between the participants.

"… (Methodology) made possible to incorporate conflicts in perceptions and in judgments in the model."

Q3. How are these conflicts incorporated in the methodology?

Ans. By conflicts, I mean that criteria are contradictory, this is the principle of multi-criteria otherwise it would be a uni-criteria problem.

Q4. Participants can change their perceptions during a process. Did this happen in your case? (If yes) Was there any way to incorporate these changes into the methodology?

Ans. There was a debate on which criteria to incorporate. Some criteria which were thought not relevant by some persons were then included because the proposer of this criteria had the chance to explain why these criteria were important to include.

4.4 Discussion and Results

Based on the framework, the elements related to the understanding of interventions were selected from the paper and discussed with the author. If something was not clear, it was discussed in detail face to face or via e-mail in form of questions. The idea was to have a logical acquisition of knowledge based on the framework.

The main ideas gathered from the papers and through discussion with authors led to important insights related to the framework.

Table 4.3
Results of elements after analysis form papers and interviews

Element	Description
Knowledge Transition & Integration	An increased ability to integrate and transit knowledge will help the facilitators in a successful intervention.
Experience	From the interviews, it became evident that past experience helps the facilitator in order to understand the problem situation and selection of a methodology.
Social Skills	The ability to analyze differences of opinion due to social factor and negotiations with actors involved helps in a successful problem structuring intervention.
Cost Effectiveness	In view of the most of the members of community, time is the main cost of using problem structuring methods in interventions.
Transparency	A clear representation of differences of opinion will lead to greater transparency which will result in a greater understanding of problem structuring interventions
Regulation	According to experts in community, the lack of proliferation of problem structuring methods in some areas like Italy is because of lack of regulation or culture of doing things. Time is also a factor.

4.4.1 Utilization of PSM

The PSM are more commonly used in some countries than in others. The main reason of such differences of proliferation is the culture or way of doing things in different countries. In UK, for example, PSM use is much more because of their tendency to discussion and adherence to removing conflicting viewpoints. In Italy (as one researcher in the community) puts it, "there are no laws that regulate the preliminary phase of the decision process. The problem structuring phase is rarely considered because it is not mandatory and because it seems to delay the whole process of the project."

4.4.2 Cost-Effectiveness of PSM

Most of the researchers in the community identified the amount of time required for PSM interventions as the main cost of using PSM. As far as the financial costs are concerned, they are difficult to measure as it depends on the problem situation and intervention. In some cases, the financial costs were acceptable because the main requirement was a well structured, clear

problem representation. PSM application could be initially considered “time expensive”, but it can orient the management of the decision process and finally bring to a “time saving”, since if the decision problems are clearer and the stakeholders are obliged to express their position in relation to them, the decision process can result more rapid and successful.

4.4.3 Selection of a particular methodology

The selection of a particular methodology mainly depends on the problem situation and the knowledge of the facilitator. Some cases, facilitator is asked to deploy a specific methodology because the people involved in the intervention are familiar with that methodology. But still the main reason for selection of a particular methodology is the knowledge of the facilitator about it. Obviously, the problem situation and the previous experience of expert are defining factors as far as the selection of a particular methodology is concerned.

4.4.4 Role of social dynamics in problem structuring

Social dynamic is an important factor in problem structuring. If the dynamic is poor—if people do not ‘relate to each other’ or if there are sources of friction—then viewpoint of all the participants cannot be represented and the outcome of the activity may be disjointed. Thus, the problem structuring may either be a reflection of what one person or a small subgroup thinks is important or result in a fractured analysis that lacks coherence. Facilitators of the process can help resolve some of the tensions that may be at play, but much can depend upon their experience and inclination.

After identifying the main factors, the next task was to present the results in the form of a cognitive map (Figure 4.3). In the cognitive map, the main goal is the centre of the map and in our case the goal was to have an increased understanding of the problem structuring interventions and to highlight which factors or element effect the understanding. From the analysis of the papers and the discussion with the authors, it became clear that one of the hindrances of employing structuring methods is the huge amount of time required to apply them. Hence in the figure it is represented that an attempt to increase the understanding of the problem structuring will increase the time factor and this increase in time factor results in less proliferation of use of PSM. However a greater understanding of structuring interventions will help to increase the proliferation. So this is a kind of paradox. The ideal solution is to help the decision makers realize that it is true that applying structuring methodologies will increase the time factor but it should be seen as a positive because afterwards they will have a well structured and defined problem which they can solve easily in a less amount of time. As also identified by Keys, the knowledge integration and transition is an important element as far as the increased understanding of the structuring intervention is concerned. Hence it is represented in the map with a plus sign meaning that it will help to increase the understanding of problem solving interventions.

Another important factor to see is the experience. As already explained, the greater amount of experience will help an analyst to form a greater understanding of the problem situations and at

the same time it helps the facilitator with the selection of a particular methodology based on the situation. The past experience is also assumed to help facilitator in forming clear representation of the differences of opinions in a problem situation. That is why it has been represented as a dotted line. This clear representation will help increase the transparency which will help to have an increased understanding of the problem situation.

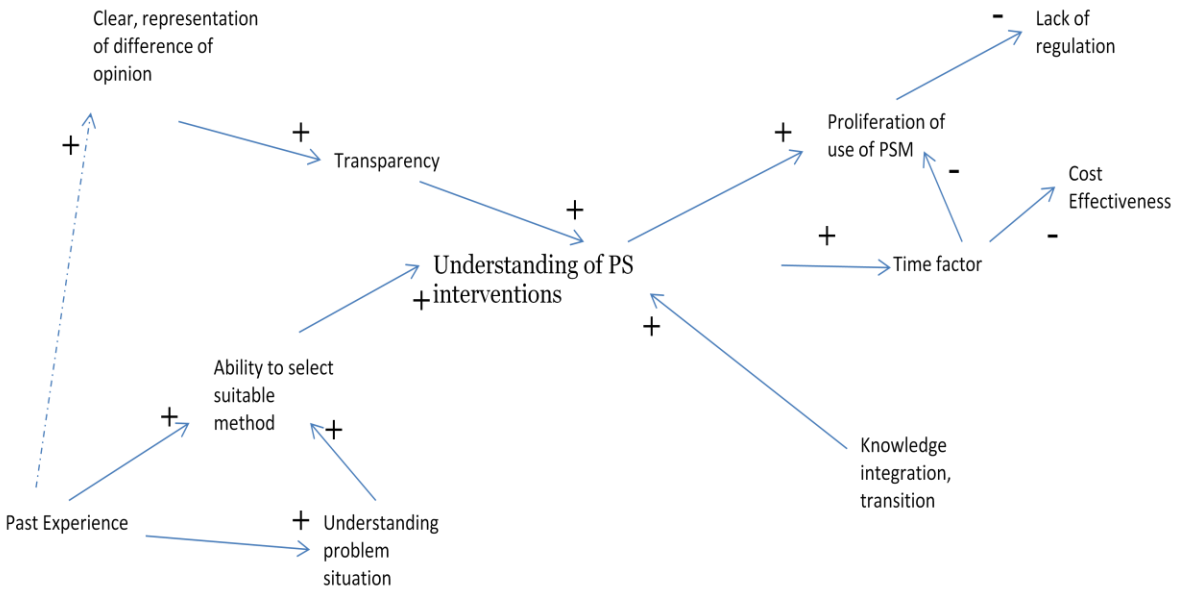


Figure 4.3: Cognitive map of the results

CONCLUSION

The research carried out during the course of this PhD is included in the context of problem structuring and the methods available to achieve it. PSM are important and powerful tools in order to structure complex, messy problem situations and this study has gone some way towards increasing the understanding of the unstructured problem situations and how can they be tackled through PSM. The main problems faced during interventions and the competences required by the expert have been investigated and identified.

The ideas presented by Keys provided the theoretical course of direction in order to study interventions. Discussions with the community members about their experience of interventions highlighted that intervention process helps human actors to communicate and non-human actors to be included in the analysis, and the success of an intervention depends on the competences of expert who should integrate the knowledge and views of actors. This study has also pointed out the importance of knowledge transition and integration, social dynamics, motivation and behavior of actors in a successful process of intervention. Interventions have to be viewed as complex interaction between various human and non-human actors who are pursuing their personal interests.

The suggestions and results concerned with the intervention do not intend to make rigid rules about how an intervention should be carried out. In fact, they are useful for learning more about the complex process of interventions and point out the necessary competences required for a successful intervention. These suggestions and results do not represent rules for action but hopefully, they can be used in order to increase the understanding about interventions, in relation to unstructured problem situations, the use of PSM and importance of multimethodology and their theoretical backgrounds.

Results achieved by Specific Goals

SG1. State of art

- General overview of PSM
- Identification of research opportunities
- Review of journal articles
- Review of books
- Development of knowledge base to meet aims of research
- Identification of leading researchers in field

SG2. List of PSM

- Identification of PSM most widely used in literature

- Identification of criteria used by authors in making their list of PSM
- Grouping of PSM and similar methods

SG3. Multimethodology

- Identification of the need for combining methods
- Indication of the importance of multimethodology
- Steps to consider when combining PSM and MCDA

SG4. PSM intervention and competence

- Identification of elements that can lead to successful PSM intervention
- Effect of social dynamics on the intervention process
- Importance of knowledge transition and integration in interventions
- Competences required for an expert use of PSM
- Relationship between PSM use and culture
- Drawbacks of PSM and ways to improve them

Research Scope and Limitations

The research scope is the analysis of the need of problem structuring for messy problem situations and, in particular, of the tools that can facilitate problem structuring. As the concepts of OR, MS and system sciences are all used in the thesis, this study aims to facilitate readers in this field to face complex and unstructured problems. The research could have been improved by making a greater community of researchers specifically for the SG4 but it was limited by time. Another limitation is that the field of PSM is not very commonly used in Italy and the university offers no extensive courses related to PSM.

Dissemination

- Fahad Mehmood (2014). Interaction between Problem Structuring Methods (PSM) and Multi-Criteria Decision Analysis (MCDA). 44th Annual Conference of the Italian Operational Research Society, Como.

- Fahad Mehmood, Mohammad Hassannezhad, Tahir Abbas (2014) Analytical investigation of mobile NFC adaption with SWOT-AHP approach: A case of Italian Telecom. In: 7th International Conference of Interdisciplinarity in Engineering, Romania, 10-11 October 2013. pp. 535-541

- Mohammad Hassannezhad, Marco Cantamessa, Francesca Montagna, Fahad Mehmood (2014) Sensitivity analysis of dynamic cell formation problem through meta-heuristic. In:

7th International Conference Interdisciplinarity in Engineering, Romania, 10-11 October 2013. pp. 186-195

- Fahad Mehmood (2013). Location estimation of digital signage. EURO-INFORMS Joint International Meeting, Rome.

- Fahad Mehmood. Business Models and Strategies of M-Commerce: A Review. The Journal of Internet Banking and Commerce (Under review).

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APPENDIX

Actor Network Theory (ANT)

Actor Network Theory (ANT) is an approach to social theory and research which originated in the field called "social studies of science and technology" and evolved from the work of Michel Callon (1986) and Bruno Latour (1988), at the Ecole des Mines in Paris, and the British sociologist John Law (1987). They observe that the introduction of innovation, any scientific or technologic project and also any organizational change are influenced by a lot of factors, things that have to be done and interdependent social practices.

ANT is above all used as an analysis method for studying the reasons, the causes of successfully or unsuccessfully happens (e.g introduction of new medicaments, of new clinical examination, etc.), but it is also a methodology helping analysts and decision makers to introduce innovation (Tatnall and Gilding, 2003; Latour, 1999; Law, 2007) .

A multi-step methodology was proposed by the authors and described by some ANT applications (see for instance Williams-Jones and Graham, 2003 and Mähring et all, 2004).

The first step may be called "identification and definitions of the actants". All the involved actors have to be identified and defined in terms of identity (i.e. ambit in which they mostly act or are acted on in the networks of practices) and their relationality, as arguments or functors in the networks of interactions (including the interactions by which they are observed, named, …). The name "actants" is used in ANT to indicate both human and non-human actors that assume identities according to prevailing strategies of interaction (Bardini, 2001).

A second step is the progressive constitution of an actor-network in which actors' identities and qualities are defined during negotiations between representatives of human and non-human actants. In this perspective, "representation" is understood in its political dimension, as a process of delegation. The most important of these negotiations is "translation," a multifaceted interaction in which actors (1) construct common definitions and meanings, (2) define representativities, and (3) co-opt each other in the pursuit of individual and collective objectives. In the actor-network theory , both actors and actants share the scene in the reconstruction of the network of interactions leading to the stabilization of the system. But the crucial difference between them is that only actors are able to put actants in circulation in the system (Bardini, 2001).

The process of translation consists of three major stages: problematization, interessmant, and enrolment. Problematization is the first moment of translation during which a focal actor, who can create an alignment of the other actors' interests with their own, is identified. This actor establishes itself as an obligatory passage point (OPP, a point in the networks that is connected to all the others, or through which the other actors must pass through), defines identities and interests of other actors that are consistent with its own interests, and thus "rendering itself

indispensable" (Callon, 1986), activates relationships or modifies the existing relationships, interests.

Interessmant is the second moment of translation which involves a process of convincing other actors to accept definition of the focal actor (Callon, 1986) and the identities that are assigned to them during problematization. Actions and procedures may be different and are relative to the nature of the links between focal and other actors. A specific space of exchange is created and defines what each actant can obtain if included in the network (Gherardi, 2000).

Enrolment is the moment that another actor accepts the interests defined by the focal actor. By the enrolment, all the significant non-human actors (influencing factors or entities, artifacts or devices, such as images of many sorts, databases, standards, rules of law, norms, models, texts, journal articles, conference papers and presentations, grant proposals, patents and so on) that are central to the process of gaining credibility and induce actors' behaviors consistent with the focal actor are identified. A trial and error procedure is activated because several attempts are required in order to identify the adequate non-human actors.

ANT is concerned with the processes by which scientific disputes become closed, ideas accepted, tools and methods adopted - that is, with how decisions are made about what is known (Van House, 2003). These decisions are often - usually - temporary, but closing the black box, in Latour's terms, of disputes allows people to take the work of others as a resource and move on, rather than continually reproducing and questioning it. According to their model, the work of science consists of the enrollment and juxtaposition of heterogeneous elements - rats, test tubes, colleagues, journal articles, funders, grants, papers at scientific conferences, and so on - which need continual management. They conclude that scientists' work is "the simultaneous reconstruction of social contexts of which they form a part - labs simultaneously rebuild and link the social and natural contexts upon which they act."

ACTOR NETWORK FRAMEWORK

(Keys, 2006) provides the idea that experts in any field deploy six types of knowledge that were first presented by (Fleck, 1998): formal knowledge, instrumentalities, informal knowledge, contingent knowledge, tacit knowledge, and meta-knowledge. Each type of knowledge is applied according to the ideas and view of an expert and the form and content of this knowledge alters as expertise is gained. The nature of the knowledge held by an individual and how it is deployed significantly determines whether that person is considered to have expertise. Actor Network Framework is a model that provides detail on "how the Fleck's categories of knowledge relate to expertise" (Keys, 2007). These typologies, that are not independent, may be only a stimulus for us; they may be used to facilitate the description of the expertise of the involved experts.

The actor-network framework views each intervention into a real-world situation as a project led by an analyst who manages and controls it through a network of relevant, human and non-

human, actors." The analyst constructs a network for each project connected with other networks relating to other interventions with which they are, have been, or will be involved. An actor-network consists of eight categories; analytic and role paradigms, social and technical actions, immediate and longitudinal situations, and public and private methodologies. Analytic and role paradigms provide the analyst with a set of assumptions about how they and the analysis they facilitate relate to the surrounding world. Social and technical actions describe the work analysts undertake as they interact with elements of the network and its environment. The immediate situation captures within its boundary those elements of a situation an analyst deems relevant and this is connected in some way, tightly or loosely, to previous, present, and possible future projects contained in the longitudinal situation. Finally, public methodologies are those explicit statements of how to proceed in a situation accessible to any individual. In contrast, private methodologies are tacit, personal to an analyst (who may not themselves be fully aware of their content), and underpin how they proceed with their practice. (Keys, 2007)

They are analytic and **role** paradigms (provide the analyst with a set of assumptions about how they and the analysis they facilitate relate to the surrounding world); **social** and technical **actions** (describe the work analysts undertake as they interact with elements of the network and its environment); **immediate and longitudinal situations** (The immediate situation captures within its boundary those elements of a situation an analyst deems relevant and this is connected in some way, tightly or loosely, to previous, present, and possible future projects contained in the longitudinal situation); public methodologies (are those explicit statements of how to proceed in a situation accessible to any individual) and , in contrast, **private** methodologies (are tacit, personal to an analyst (who may not themselves be fully aware of their content), and underpin how they proceed with their practice)

These categories should be analyzed and transformed in a consistent framework to be proposed in the investigation after the reading of each paper/case.

In order to improve the practicality of PSM, Keys suggests that the focus should be on knowledge about general process-design, as opposed to specific instances of how analysts act during interventions. Keys identified three significant processes in the construction and management of actor networks: defining the network; managing the network and dissolving the network.